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Economic Impact of Regulating Chlorofluorocarbon Emissions from Aerosols: A Retrospective Study

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THE ECONOMIC IMPACT OF REGULATING CHLOROFLUOROCARBON EMISSIONS FROM AEROSOLS: A RETROSPECTIVE STUDY

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FOREWORD

In May of 1977, the U.S. Environmental Protection Agency, along with the Food and Drug Administration and the Consumer Product Safety Commission, proposed a time table for the phase-out of the use of chlorofluorocarbons for nonessential aerosol uses (42 FR 24542, 42 FR 24536, 42 FR 24550; 5/13/77). The final rule was promulgated in March of 1978 (43 FR 11318-11325, 3/17/78). International Research and Technology Corp. (IR&T), under Contract No. 68-01-1918, had performed the propsective analysis of the economic impact of this rule.

(the study is)

In March of 1980, JACA Corporation was selected to develop a retrospective study of the economic impact of the CFC aerosol rule. The purpose of this contract was to evaluate the economic impact and cost estimates in the original economic impact studies and to construct estimates of the actual economic burden imposed once the total ban had taken effect. EPA's intention in sponsoring this study was to improve its ability to conduct similar economic analyses by examining how markets actually responded to a product ban regulation, and by developing appropriate analytical methodologies. The study was not intended to address prospectively the economic costs and benefits of continuing the aerosol ban. ✓

The JACA study was not meant to be a full cost-benefit analysis of the rule. There was no attempt made to measure the possible benefits to the environment and society resulting from the ban of chlorofluorocarbons in aerosols. This study is fundamentally a cost analysis. It is an attempt at measuring the economic impact on chemical producers and aerosol fillers, marketers, and users. The study has limitations and its estimates should be viewed in light of these limitations.

JACA found it necessary to attribute to the aerosol ban regulation all costs and lost profits incurred by manufacturers, fillers, and formulators, including those costs resulting from consumer response to publicity surrounding the ozone depletion hypothesis and in response to the labeling requirement for CFC aerosol products. The latter was promulgated in August 1977 by the Consumer Product Safety Commission (42 FR 42780), and became effective February 20, 1978. A labeling requirement was also announced by the Food and Drug Administration on April 29, 1977 (42 FR 22018-22034). Because no

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year-by-year surveys of consumer attitudes were taken, it was impossible to separate consumer response to the news and the CPSC/FDA labeling requirements from the anticipated EPA ban.

Included in JACA's estimate of lost profits is the impact of declining demand in aerosol products which did not contain chlorofluorocarbons at the time of the ban. Items such as bathroom cleaners, shaving cream, insecticides, oven cleaners, rug cleaners, and whipped cream were not produced using chlorofluorocarbons. These products account for over 25 percent of the lost aerosol product sales between 1975 and 1979. JACA found that consumer confusion over which aerosol products contained chlorofluorocarbons caused the decline in demand for all aerosol products. The extent of the true causal relationship between the ban and reduced sales of nonCFC-propelled products is unknown.

The JACA study lacks extensive sensitivity analysis. When data were unavailable, the assumptions that were made often did not give a range of estimates. JACA assumes, for example, that profits for the substitutes of CFC aerosol products were not unusually enhanced by the ban. They had no data to the contrary and so made this conservative assumption. The CFC aerosol ban caused some consumers to switch to alternative products, thus increasing the demand for these products. To the extent that excess economic profits were generated, these sectors gained from the regulation and these gains should be used to offset some of the loss when evaluating the overall cost to society. Since JACA had not generated this data, they assumed that excess capacity did not exist in these sectors and that any new capacity that was installed would reap only normal economic profits. On the other hand, the report assumes that profits lost by the sectors directly impacted by the ban were proportional to the lost sales. Profits lost were actually greater since demand for the products of these firms decreased after the ban.

Given its limitations, the JACA report is useful as a comparison to the IR&T prospective report and highlights the market sectors most severely impacted by the ban. It gives an indication of where new products were created, the cost of substitutes utilized by firms, and the problems encountered by firms when CFCs became unavailable.

Ellen Warhit
Project Officer
U.S. Environmental Protection Agency

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JACA is indebted to members of industry and of agencies of the Federal government for their efforts on behalf of this project. We are particularly grateful to industry for the time and care it took in answering our wide range of questions, even though the individuals involved were aware that this was a retrospective study. Thus, there could be no obvious advantages accruing to them in helping us.

We also wish to thank several people at JACA for their assistance. Patrick Rafferty investigated and wrote the chapter on safety. James Blaylock wrote the book reports. Kevan Deardorff assisted in all quantitative work. Ross Goldstein was also of help in the quantitative estimation of impact. Virginia Hathaway and Cherrie Schnaithmann edited this report. Nancy Block did her usual remarkable job of typing the manuscript.

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Chapter I

SUMMARY

This study summarizes the economic impact of government regulations on the use of chlorofluorocarbons (CFCs) as aerosol propellants in the United States, now that a ban on their use has been in effect since December 1978. The effects of regulation on both consumers and producers of aerosol products are evaluated using data available through 1980.

In June 1974, it was first theorized that there would be a depletion of the stratospheric ozone layer due to the emission of CFCs into the atmosphere. It was hypothesized that if this depletion were to occur, there would be an increase in the amount of ultraviolet light that reached the earth, and that a sufficient increase could cause climatic change and harm human, plant, and marine life. The National Academy of Sciences estimated that worldwide aerosol usage for the two most widely used CFCs (CFC-11 and CFC-12) was about two-thirds of total CFC usage in 1974. The United States was the largest producer and user of CFCs in the world.

Both the Federal government and the American public reacted quickly to the announcement of the ozone depletion hypothesis. Additional studies were undertaken. At least two Congressional hearings were held in late 1974, and numerous articles appeared in newspapers reporting the link between the ozone depletion theory and aerosol use. Some consumers, aware of this concern, shifted their purchases from products packaged in aerosol form to the same products packaged in nonaerosol form as early as the third quarter of 1974.

The U.S. Environmental Protection Agency (EPA), the Consumer Product Safety Commission (CPSC), and the U.S. Food and Drug Administration (FDA) announced their intentions to regulate the use of CFCs as aerosol propellants in 1976. The actual regulations were of two types. The first was a requirement that aerosol products propelled by CFCs be labeled. These labeling requirements by FDA and CPSC were announced in 1976 and became effective in 1977 and 1978 respectively. The second was a ban on CFCs as aerosol propellants for all but a few essential uses. This ban was announced by FDA and EPA on March 17, 1978 and was phased-in as follows:

1. All production of CFCs intended for nonessential aerosol use was to cease by December 15, 1978, and
2. Interstate shipments of products containing CFCs were banned after April 15, 1979.

The primary objective of this study is to estimate the actual economic impact on consumers and producers of the regulations on CFC-propelled aerosols. Only the direct costs to the major industrial sectors affected by regulation are quantified in this report. Secondary effects are also discussed. This study makes no attempt to examine the benefits from these regulatory actions.

The results indicate there has been only a small quantifiable economic impact of the regulations on consumers, but finds an impact on producers of aerosol products. Specifically, a decline in producer profits due to lost aerosol sales totals about $1 billion, in 1976 dollars, between 1975 and 1990, or an average of about $125 million in lost profits per year in 1976 dollars for each of these years. The profit losses largely follow from estimates of 25.8 billion units of containers, valves, and aerosol units not filled between 1975 and 1990 as a result of regulation, and of 8.8 billion pounds of CFCs not produced that otherwise would have been. In addition, some producers incurred once-and-for-all costs of reformulation and initial capital costs for equipment conversions of about $400 million in 1976 dollars. Jobs lost due to regulation are estimated to be approximately 8,700 by 1979, but it is reasonable to assume that the majority of people who lost jobs found alternative employment elsewhere in the economy. The extent to which these workers who were laid off as a result of these job losses found reemployment elsewhere in the economy is not explicitly calculated.

A secondary objective of this study is to evaluate the estimates of economic impact in the prospective studies which were used by EPA and FDA in the development of CFC regulations. Only one prospective study [36] quantified its predictions of the economic impact that might result from regulation.

This summary reviews six topics. These are:

1. A description of the industry
2. Selection of the period for analysis

3. Economic impact on consumers
4. Economic impact on producers and labor
5. Comparative safety of alternative propellants
6. Comparison with prospective studies.

DESCRIPTION OF THE INDUSTRY

An aerosol product consists of one or more active ingredients, as well as inert ingredients such as solvents, which are dissolved or suspended in a propellant and sealed under pressure in a container. These propellants are either liquified gases such as CFCs and hydrocarbons (HCs), or compressed gases such as carbon dioxide.

CFCs are organic chemical compounds consisting of chlorine, fluorine, carbon, and (sometimes) hydrogen. They are used in aerosol products because of their low flammability, chemical stability, low toxicity, inertness, and a variety of other properties that aid in the formulation of aerosol products (such as solubility and vapor pressure characteristics). Stated differently, CFC propellants do not interfere or react with the active ingredients in aerosol products; they reduce or eliminate flammability hazards of other formulation components; and they readily supply the range of spray characteristics desired. Offsetting these advantages prior to 1974 were the higher cost of CFCs relative to the chief alternative propellant, HCs.

Thus, prior to 1974, CFCs were primarily used for products in which their fire retardant property or their inertness were viewed as being of critical importance, whereas HCs were the chief propellant in aqueous-based products in which flame suppressant features were less important. CFCs were the primary propellant in pan sprays, pharmaceutical products, some industrial products, and in most alcohol-based personal products (hairsprays, antiperspirants, deodorants, and colognes). HCs were used in water-based aerosol products such as shaving lathers, window cleaners, spray starches, room deodorants, and space insecticides.

A small number of aerosol products (5 to 10%) are propelled by compressed gases rather than CFCs or HCs. Compressed gases have a major advantage over other propellants in low-temperature situations and are also nonflammable and inexpensive. The present barrier to wider use of compressed gases as propellants is that they produce a coarse spray and uneven pressure characteristics over the lifetime of the product. As a result, compressed gases are chiefly used in automotive products (including windshield de-icers and tire traction sprays) and some industrial products.

The chief industrial sectors affected by the regulation are:

1. The chemical sector
2. The aerosol sector
3. The marketers of the aerosol products.

The chemical sector includes those companies, generally large firms, that manufacture CFCs and the companies that supply the basic chemical ingredients for their manufacture. Basic chemicals include hydrofluoric acid, carbon tetrachloride, fluorspar, sulfuric acid, sulfur, chlorine, methane, propylene, and carbon disulfide. Currently four of the five domestic producers of CFCs supply the remaining aerosol market for the small number of essential-use exemptions. The chemical sector is affected because the output of CFCs for aerosol applications dropped from 443 million pounds a year in 1975 to 21 million pounds a year in 1979.

The aerosol sector is comprised of companies that produce metal and glass aerosol containers and valves, and companies that assemble and fill the containers with propellant and concentrate (active ingredient and a solvent). Container and valve manufacturers (there are 9 to 12 companies in each) suffered lost sales due to regulation, lost the investment in equipment that was dedicated to aerosol use and not suitable to other operations, and were unable to offset their losses of aerosol-related products with gains from nonaerosol sales. The same is true of aerosol fillers, of which there are about 400 companies, one-fifth having less than five employees. Concentrate suppliers are presumed to have their losses in aerosol sales offset by gains in nonaerosol sales.

A marketer distributes (markets) a particular brand of a product, for example, a hairspray or antiperspirant, and is ultimately responsible for the specific formulation for this product. Products which had been propelled by CFCs had to be reformulated to alternative propellants, a complicated process which required altering all the chemicals (active ingredients, solvents, and propellants), as well as selecting a suitable new valve and container.

The economic impact of regulation on marketers (about 500 companies) is evaluated separately from the chemical and aerosol sectors. This is because the strong presumption is made that losses to marketers due to aerosol sales were offset by gains from nonaerosol sales. This assumption was made because losses are a function of the substitution ratio of CFC aerosols to nonaerosols and such ratio data on the 30,000 CFC-propelled aerosols was not available from the marketers. Thus, the economic impact of regulation on marketers is approached through once-and-for-all costs of reformulation. (An additional set of initial capital costs to some marketers is attributable to converting capital equipment from CFCs to HCs, to the extent that some marketers also fill their own products.)

SELECTION OF THE PERIOD FOR ANALYSIS

When investigating economic impact a major analytic issue is the selection of the appropriate period for analysis. In this study, there are significant problems in determining the initial as well as termination dates.

A technical problem in determining the starting date of economic impact is caused by the fact that there are three sequential, synergistic events. These events are:

- The announcement of the ozone depletion hypothesis in June 1974
- The anticipation of regulation
- The regulations themselves, that is, the labeling requirements and the ban.

1975 is the starting date used in this summary of the report, but year-by-year calculations are provided in the body of the text.

The selection of a termination date for calculating economic impact hinges on assumptions about capital equipment and, to some extent, consumer tastes. In the case of capital equipment, economic impact in the chemical and aerosol sectors continues to the extent that capital equipment in those sectors became unemployed due to regulation, was dedicated to specific aerosol or chemical use, and could not be reemployed elsewhere. In the aerosol sector, economic impact continues to the extent that consumers find aerosols a less desirable form of dispensing a product now than they did prior to regulation.

1990 is selected as a reasonable date on which to terminate economic impact due to regulation. This selection is based on the assumption that the remaining economic life of equipment in the chemical and aerosol sectors continues only until 1990. For the aerosol sector, it is also based on the industry-held hypothesis that consumers will once again find aerosols more desirable and that by 1990, consumer tastes with respect to aerosols will return to the pre-1974 situation.

ECONOMIC IMPACT ON CONSUMERS

For consumers, the effect of a ban is to make a set of products unavailable that would have been available in the absence of regulation. Output of the banned product dropped from approximately 1.45 billion units in 1973 to almost zero units by the end of 1978. The significance of this loss to consumers depends upon the relative price of substitute products, their availability, and their quality.

This study concludes that the loss to consumers that is directly attributable to regulation and that can be quantified has been relatively small. More specifically, the conclusions are:

1. Prices. There are three results: one, the nominal price of aerosols probably did not increase due to reformulation; two, the real price of an aerosol, that is, the nominal price of an aerosol relative to the wholesale price index for the U.S. economy as a whole, fell throughout the Seventies; and finally, the price of an aerosol product relative to the price of a nonaerosol product also fell throughout the Seventies. Since real and relative aerosol prices began to decline dramatically as early as 1971, it is not possible to attribute the decreases since 1978 to reformulation.
2. Quantity of Nonaerosol Products. There has been an increase in the quantity of products available in nonaerosol form as a result of regulation, and this increase represents a nonquantifiable benefit of the regulation.

3. Quality. The quality of aerosol products, as perceived by consumers, has decreased due to regulation. (The exceptions to this perceived decrease in quality are the essential-use exemptions to the ban, because CFCs continue to be used in these cases.)
4. Consumers' Surplus. As a result of the ban, there has been a loss in consumers' surplus (and hence, a decline in social welfare) because a product that consumers purchased prior to the ban is no longer available. Despite this, the size of the loss in consumers' surplus is probably relatively small because of the availability of fairly close substitutes for the banned CFC-propelled products.

ECONOMIC IMPACT ON PRODUCERS AND LABOR

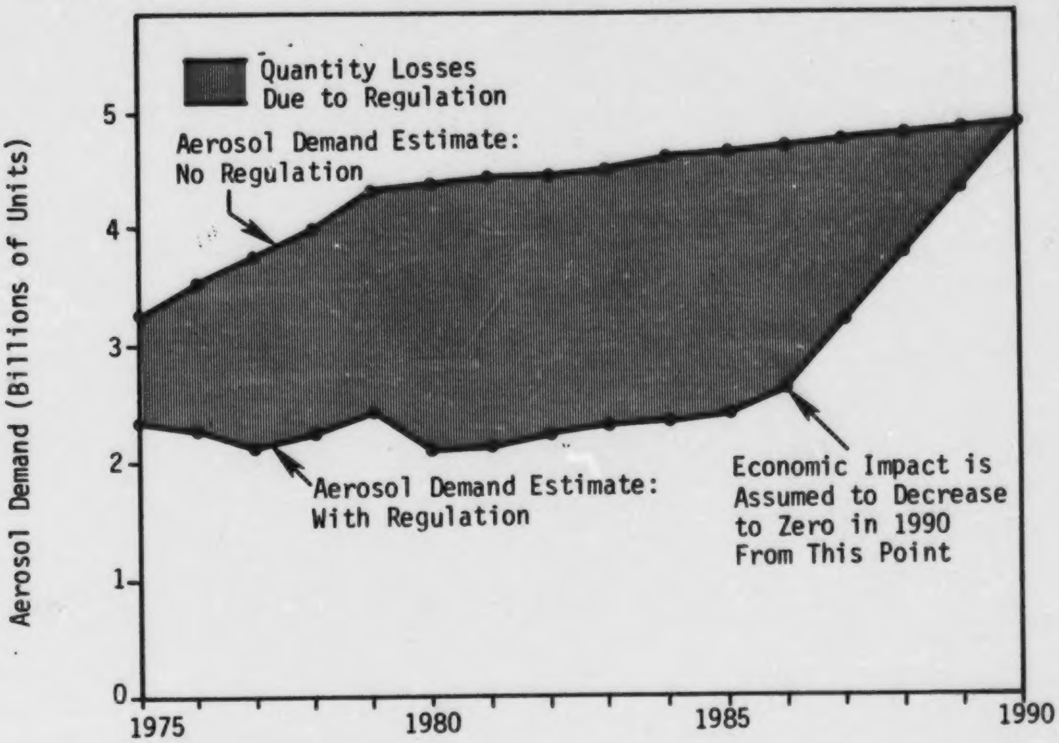
The major quantifiable costs to industry and labor fall into four categories:

1. Lost quantities and lost profits in the aerosol and chemical sectors
2. Initial capital costs to fillers and marketer-fillers of converting equipment from CFCs to HCs
3. Once-and-for-all costs of reformulating products from CFCs to alternative propellants
4. Lost jobs in the chemical and aerosol sectors.

Lost Quantities and Lost Profits in the Aerosol and Chemical Sectors

Two measures of economic impact allow quantification of losses due to regulation across a fairly wide range of industrial sectors. These two measures are:

1. Estimates of the "quantity wedge", which is the difference in the quantity that would have been produced in the absence of regulation and the quantity that was produced with regulation, and
2. Estimates of profit losses that are directly attributable to lost quantities, that is, the net present value (NPV) of producers'

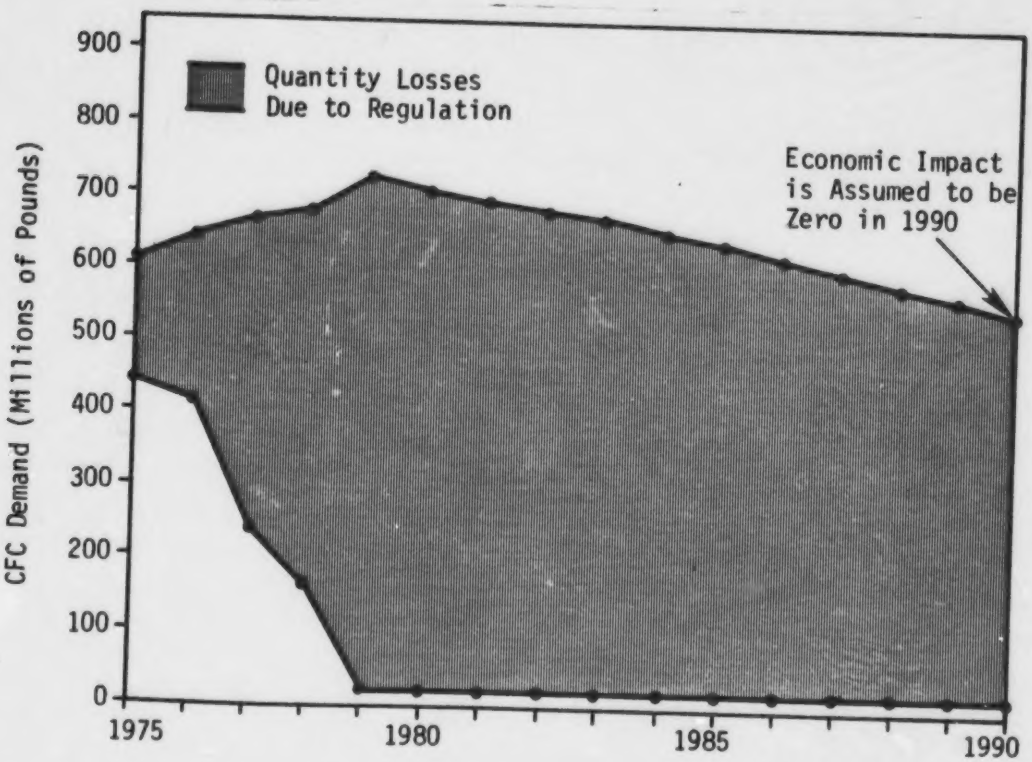


Graph I-1. Aerosol Quantity Losses.
Source: JACA estimates.

> profit streams foregone. These lost profits are real resource costs to the U.S. economy. This is because capital became unusable, thus reducing profit-type income, hence the net national product that could have been generated by this capital.

These losses are calculated for both the aerosol and chemical sectors.

This study finds that the quantity losses due to regulation are 25.8 billion units of containers, valves, and units of aerosols filled between 1975 and 1990, and 8.8 billion pounds of CFCs not produced that otherwise would have been during the same time period. (The quantity implications for nine precursor chemicals are also estimated.) Graph I-1 summarizes the time-



Graph I-2. Chlorofluorocarbon Quantity Losses.
Source: JACA estimates.

profile for the aerosol sector (containers, valves, and fillers). Graph I-2 summarizes the quantity losses due to regulations for CFCs (in the chemical sector).

The net present value of profits foregone due to these lost quantities is estimated to be about $1 billion in 1976 dollars. These profit losses include those of the aerosol and chemical sectors, but not of all sectors affected by regulation. The calculations also assume that above normal profits indirectly generated in sectors making substitute products are zero. Of this $1 billion, $789.3 million is attributable to lost quantities in the aerosol sector. The remaining $248.9 million was lost in the chemical sector. A numerical summary of the results for each industrial sector is in Table I-1.

Table I-1

QUANTITY LOSSES AND LOST NPV OF FUTURE PROFIT STREAMS, 1975 TO 1990, FOR AEROSOLS AND CHEMICALS

Industrial Sector	Quantities Lost Due to Regulation	NPV of Profit Streams Foregone Due to Quantity Losses (Millions of 1976 Dollars)[a]
The Aerosol Sector:*		
	(Billions of Units)	
Containers	25.8	104.8
Valves	25.8	46.4
Fillers	25.8	638.1
The Chemicals Sector:**		
	(Billions of Pounds)	
CFCs	8.8	124.1
Hydrofluoric Acid	2.0	24.9
Carbon Tetrachloride	10.5	52.3
Fluorspar	4.4	9.1
Sulfuric Acid	5.9	3.6
Sulfur	2.1	1.4
Chlorine	15.3	25.1
Methane	0.3	0.4
Carbon Disulfide	2.1	5.6
Propylene	0.8	2.4
Total		1,038.2

[a] Profits are profits net of depreciation but before taxes in order to reflect both the costs to industry and the costs to society of regulation. A real discount rate of 9.37% was used to discount to profit streams to 1976. The choice of 9.37% is based on the [(dividends/price) x 2] over the business cycle, 1975 to 1979, and is intended to reflect the greater riskiness of investment for private industry than that for the Federal government.

*The key assumptions that allow one to extend economic impact for the aerosol sector to 1990 are: (a) that capital equipment became unemployed due to the aerosol ban, that it could not be converted to other uses, and that it had a remaining economic life of at least 15 to 20 years; and (b) that consumers find aerosols a less desirable product than they would have in the absence of regulation. There are two reasons for reducing economic impact in the aerosol sector to zero by 1990. One is changing consumer tastes, namely, consumers are assumed to conclude by 1990 that aerosols are as desirable a dispensing form relative to their alternatives as before the announcement of the ozone depletion hypothesis. The other assumption is that capital has no economic life beyond 1990.

**The key assumption that allows one to extend economic impact for the chemicals sector to 1990 is that capital equipment became unemployed due to the aerosol ban, that it could not be converted to other uses, and that it had a remaining economic life of 15 years. To the extent that the remaining functional (economic) life of equipment in the chemicals sector is indefinite, then the lost quantities and the lost profit streams extend indefinitely and, the economic impact of regulation on the chemicals sector is underestimated in these calculations. This is because economic impact is terminated in 1990.

Initial Capital Costs of Converting Equipment

The second economic impact is the cost of converting filling lines that were designed to fill aerosols with CFCs to lines capable of handling the more flammable HCs. This one-time cost was borne by fillers of aerosol products and by those marketers who also fill their own products.

The total cost of these conversions is estimated to have been $98.7 million, in 1976 dollars. Of this, $66 million was spent by marketer-fillers and $32.7 million by fillers. Costs are higher for marketers than for fillers because marketers converted a larger proportion of filling lines (75%) to HC filling, and because the average amount spent per line was higher for marketers ($220 thousand compared with $60.3 thousand).

Once-and-for-All Costs of Reformulating Aerosol Products

Regulation required that a set of products propelled by CFCs be reformulated to use alternative propellants. This involved an estimated 30,000 products and consumed two to three years of the laboratory time of marketers and fillers. The costs of these reformulations, induced by the ban on CFCs, are estimated to have been about $337 million, in 1976 dollars, for the 18,280 products for which reformulation costs are available. The costs of research opportunities that were postponed or permanently foregone due to regulation cannot be quantified.

Jobs Lost

The reduced demand for aerosols has had an effect on the number of jobs in those sectors. Based on preregulation data available from the Federal Task Force on the Inadvertent Modification of the Stratosphere (IMOS) [21] and Commerce [76] reports, and assuming proportional relationships between labor inputs and chemical or aerosol output, it is estimated that approximately 8,700 jobs were lost between 1975 and 1980 due to regulation, although it is reasonable to assume the majority of workers found reemployment elsewhere in the economy. Of this 8,700 jobs, approximately 3,200 jobs were in the chemical sector, and 5,500 were in the aerosol sector; but the cost of these lost jobs to individuals and to society depends on how many people were laid off and on how easily and quickly any affected workers were able to find alternative employment, and at what wage rate.

COMPARATIVE SAFETY OF ALTERNATIVE PROPELLANTS

The replacement of nonflammable CFCs with flammable HCs has raised the possibility of changes in the safety of aerosol products to the consumer. Based on CPSC data, injury rates appear to have increased with the sale of HC products during the Seventies, but the lack of specific data prevents any conclusions from being drawn. The increased risk of aerosol products is demonstrated by the fact that the percent of aerosol-related injuries attributed to fire and explosion increased six-fold in the five years from 1975 through 1979. The conclusion that HC products are more likely to induce injury by fire and explosion is substantiated by the physical and chemical properties of HCs and CFCs.

Over 90 percent of the deaths caused by aerosol products have been the result of their deliberate abuse by teenagers seeking the euphoria induced by inhaling CFCs. The Sudden Sniffing Death Syndrome has been attributed to the adverse effects that CFCs can have on cardiac rhythms. The number of recorded "sudden sniffing deaths" declined from a high of 70 in 1976 to a low of 12 in 1979, paralleling the decline in the production of CFC units. This study has been unable to quantify the relative effects of the regulation, public education, and changing drug abuse patterns on the decline in the death rate.

The safety of warehousing aerosol products has been an area of concern to the insurance industry because of a number of warehouse fires in the late Seventies. As a result, new safety requirements are under consideration. Although the costs involved in meeting these requirements are significant, whether or not these costs can be attributed to CFC regulations remains highly controversial because adequate tests have never been performed.

COMPARISON WITH PROSPECTIVE STUDIES

The prospective studies vary somewhat in data, methods, and conclusions. The prospective study by the U.S. Department of Commerce [76] provides a good deal of quantitative and qualitative information about chemicals and aerosols in 1975 and thus a good basis on which to project actual economic impact.

The results of this study can be compared with those of the International Research and Technology, Inc. (IR&T) report [36], which was the only prospective study to quantify estimated economic impact. Neither study finds that consumers would bear much of the quantifiable burden of the ban. Both find that regulations would cause substantial losses to producers. IR&T anticipated an impact of $1.4 billion in value added losses in 1976 dollars. This study finds about $1 billion in profits lost, in 1976 dollars, due to regulation and $400 million in one-time costs.

There are differences between the two reports. The IR&T study measured economic impact as losses in value added and also assumed the effects of regulation would last only four years. This study estimates impact primarily as profits foregone due to regulation and concludes economic impact on producers is more appropriately quantified for 15 years. The prospective study found the primary impact of regulation was on marketers of aerosol products, whereas this study finds profit losses are greatest for the aerosol sector, particularly for fillers.

From an analytic point of view, lost profits due to regulation is the more appropriate measure of economic impact. The use of value added as a criterion of economic impact assumes that both labor and capital become unemployed due to regulation and cannot be reemployed. The more reasonable assumption is that capital cannot be reemployed, but that labor can.

LIMITATIONS TO THE ANALYSIS

There are limitations to the analysis, three of which are discussed here.

One, the study generates the appropriate data for the cost side of the benefit-cost equation for society, but it does not generate any data for the benefits side, if in fact benefits to society did result. Benefits analysis was outside of the scope of work; the interested reader can use benefits data such as those generated by Bailey [8,9] for this purpose. The cost side consists of the NPV of the loss in consumers' surplus, the NPV of the transitory lost profits due to idled capital equipment, and the costs to marketers of reformulating their products from CFCs to HCs.

The changes in health and safety to workers and consumers that occurred as a result of the use of alternative propellants were not converted into net costs, if any, in this analysis. An example of this is information on the increased injuries and deaths from aerosol filler fires as a result of the increased use of HCs as propellants and the decrease in sudden sniffing deaths associated with decreased CFC usage. Although the conversion of relative safety and health data into costs and benefits was outside our scope of work, it is a limitation of the current analysis.

Three, there is very little formal sensitivity analysis in the body of this report. In lieu of formal sensitivity analysis, all of the assumptions about (and calculations of) economic impact have been made explicit, so that the interested reader may estimate the implications of our choice versus his/her own. We can, however, cite assumptions which, if altered, would decrease economic impact and others which, if altered, would increase economic impact.

There are at least four items which, if altered, decrease economic impact. They are: the decision to attribute all impact on profits from 1975 on as due to regulation; the assumption that there is no independent impact of the ozone depletion hypothesis; the inclusion in economic impact of reduced sales of all aerosols (rather than only those which were propelled by CFCs); and the exclusion of secondary, positive impacts due to increased nonaerosol sales as a result of regulation.

There are four factors which, if altered, increase economic impact. They are: the use of uniform, published profit rates for calculating the NPV of profit streams foregone; the assumption for the aerosol sector that consumer tastes with respect to aerosols will return to their former level beginning in 1986; the assumption for marketers that the gains for nonaerosols exactly offset losses from aerosol sales; and the exclusion of secondary negative impacts due to decreased aerosol sales.

Chapter II

SELECTION OF THE PERIOD FOR ANALYSIS

A major analytic issue when investigating economic impact is selecting the appropriate period for analysis. In the case of regulations on the use of CFCs as aerosol propellants, there are significant problems in determining both the initial and the termination dates.

THE INITIAL DATE

When examining the economic impact of a regulation, the date when the ban on the use of a product is first announced would normally be the date from which the analysis would begin. However, in the case of CFCs, there was a considerable amount of negative publicity that had an impact on aerosol sales even before they were actually regulated.

In June 1974, it was first theorized that there was a depletion of the stratospheric ozone layer due to the emission of CFCs into the atmosphere. It was hypothesized that if this depletion were to occur, there would be an increase in ultraviolet light that reached the earth, and that a sufficient increase could cause climatic change that would harm human, plant, and marine life. The National Academy of Sciences estimated that worldwide aerosol usage for the two most widely used CFCs (CFC-11 and CFC-12) was about two-thirds of total CFC usage in 1974. The United States was the largest producer and user of CFCs in the world.

Both the Federal government and the American public reacted quickly to the announcement of the ozone depletion hypothesis. Additional studies were undertaken. At least two Congressional hearings were held in late 1974, and numerous articles appeared in newspapers reporting the link between the ozone depletion theory and aerosol use. It is widely recognized that the announcement of the ozone depletion hypothesis had a rapid effect on consumers. The extent to which the hypothesis was immediately linked to the use of aerosols by the public has been discussed by Schiff [69]. Some consumers shifted their purchases from products packaged in aerosol form to the same products packaged in nonaerosol form as early as the third quarter of 1974. This of course affected producers of aerosol-related products.

It was not until 1976 that the EPA, CPSC, and FDA announced their intentions to regulate the use of CFCs as aerosol propellants. The first regulation was a requirement that aerosol products propelled by CFCs be labeled. These labeling requirements by FDA and CPSC were announced in 1976 and became effective in 1977. The ban was not announced until 1978.

Details of this series of events are outlined in Tables II-1 through II-6.

- Table II-1 - Dates of Selected CFC Scientific Announcements. This includes Rowland and Molina's announcement of the ozone depletion hypothesis. Early findings by prestigious scientific groups are also cited.
- Table II-2 - Dates of Media Events Concerning CFCs. These suggest an early date.
- Table II-3 - Dates of Selected CFC Regulatory Events. Information in this table suggests that government involvement in CFC regulation began as early as December 1974.
- Table II-4 - Dates of Selected Marketing Events Concerning CFCs. Information suggests reformulation efforts by propellant manufacturers and by some marketers in anticipation of regulation began as early as 1975; this inference is confirmed by Arthur D. Little, Inc. (ADL) [4, p. VI-73].
- Table II-5 - Dates of Selected Economic Impact Statements. The U.S. Department of Commerce report (dated 1975) [76] concludes that economic impact began in 1974. IR&T [36, p. 2-8] reached the same conclusions for the aerosol sectors. Wolf [99, p. 79] comments on the chemical sectors: "CFCs used as a propellant began declining in 1975, probably in anticipation of the propellant ban."
- Table II-6 - Dates of Salient CFC Regulatory Announcements: EPA, FDA, CPSC. This table suggests that only in 1976 can one attribute economic impact to the Federal government.

These tables raise the question: In what year did the Federal government -- either through its actions or inactions -- become responsible for the

Table II-1

DATES OF SELECTED CFC SCIENTIFIC ANNOUNCEMENTS

Date	Selected Scientific Announcements
June 1974	Announcement of the ozone depletion hypothesis by Rowland and Molina.[a]
May 1975	Publication of report by National Science Foundation (NSF).[b]
June 1975	Publication of report by the Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS).[c]
July 1975	First Report of National Academy of Sciences, Climatic Impact Committee.[d]
1976	Other Reports by National Academy of Sciences, including the Panel on Atmospheric Chemistry and Committee on Impacts of Stratospheric Change.[e]

[a] Molina, M. J., and F. S. Rowland, Nature 249, 810 (1974).

[b] "The Possible Impact of Fluorocarbons and Halocarbons on Ozone," Interdepartmental Committee for Atmospheric Sciences, National Science Foundation, May 1975 (ICAS 18a-FY75).

[c] "Fluorocarbons and the Environment," Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS), Council on Environmental Quality, June 1975 (GPO Stock #038-000-00226-1).

[d] "Interim Report of the Panel on Atmospheric Chemistry," Climatic Impact Committee, National Academy of Sciences, July 1975.

[e] "Halocarbons: Effects on the Stratospheric Ozone," Panel on Atmospheric Chemistry, National Academy of Sciences, 1976; and "Halocarbons: Environmental Effects of Chlorofluoromethane Release," Committee on Impacts of Stratospheric Change, National Academy of Sciences, 1976.

Table II-2

DATES OF MEDIA EVENTS CONCERNING CFCS

Dates	Media Events
9/26/74 and 9/27/74	Walter Sullivan of the New York Times had a front-page article on the scientific theory
1974	Walter Cronkite reported on CBS evening news
2/1/75	"All in the Family", a TV series with a purported audience of 43 million people, implies CFCs used in aerosols are linked to the ozone layer and cause danger to human health
Before 3/7/75	The relationship between aerosols and ozone are said to have been discussed in the New York Times, the Los Angeles Times, the Christian Science Monitor, Time, Newsweek, and Business Week.

Source: Schiff [69].

Table II-3

DATES OF SELECTED CFC REGULATORY EVENTS*

Date or Year	Federal, State, or Local	Regulatory Event
12/11/74	Federal	Two days of hearings before the Subcommittee on Public Health of Interstate and Foreign Commerce Committee on the use of CFCs as aerosol propellants; Congress adjourns before action is taken. EPA testifies.
12/11/74	Federal	Two Congressmen (Rogers and Esch) introduce the first bill to amend the Clean Air Act to ban chlorofluorocarbons if they had an effect on the stratospheric ozone layer. (The bill died in committee in 2/75.)
1/29/75	Federal	Senate Committee on Aeronautical Space Science holds hearing on CFCs.
2/27/75	Federal	IMOS holds a one-day public meeting.
March 1975	Oregon	Oregon legislates a ban on sales of CFC-propelled aerosols -- the ban to become effective in March 1977.
Sept. 1975	Federal	Senate Subcommittee on the Upper Atmosphere holds hearings for seven days.
Dec. 1975	10 States	Ten states have held hearings on whether to ban CFC-propelled aerosols.
10/11/76	Federal	Toxic Substances Control Act passes.
Dec. 1976	30 States and/or Localities	More than 30 states have held hearings on whether to ban CFC-propelled aerosols.
April 1977	New York	Bill passes requiring a warning label on all aerosols with CFCs, the label to state CFCs "may harm the environment".
8/2/77	Federal	Clean Air Act Amendments, Section 159, entitled, "Protection of the Stratosphere".

*By Federal, state, and local authorities except those by EPA, CPSC, and FDA, 1970 to present.

Sources: EPA, various newspapers, and Schiff [69].

Table II-4

DATES OF SELECTED MARKETING EVENTS CONCERNING CFCS

Date	Marketing Event
June 1975	Announcement by Johnson Wax (via full-page ads in major U.S. newspapers) that it is ceasing production immediately of its remaining 5 percent of aerosol products using CFCs.
July 1975	Announcement of CPSC finding that aerosols are not unsafe to consumers if used properly; use may continue.
April 1976	Announcement by Gillette that nonaerosol alternatives are available for all its products, including all cosmetics formerly propelled by aerosols. Similar announcements were made by other manufacturers, such as Revlon and Alberto Culver.
November 1977	Bristol-Myers announced $17 million ad campaign for Ultra Ban II, its first aerosol nonCFC antiperspirant.
June 1978	An estimated 85 percent of all cosmetics use HC propellants, not CFCs. Range of brand choice is wide within each product category. Hairspray also available in pump forms.

Source: Newspapers.

Table II-5

DATES OF SELECTED ECONOMIC IMPACT STATEMENTS

Publication Date	Author	Economic Impact Statement	EPA Contract No.
Sept. 1975	ADL	Preliminary Economic Impact Assessment of Possible Regulatory Action to Control Atmospheric Emissions of Selected Halocarbons	68-02-1349
Dec. 1975	U.S. Dept. of Commerce	Economic Significance of Fluorocarbons	
April 1977	IR&T	The Economic Impact of Potential Regulation of Chlorofluorocarbon-Propelled Aerosols	68-01-1918
Aug. 1980	Wolf	Regulatory Chlorofluorocarbon Emissions: Effects on Chemical Production	68-01-3882 68-01-6111

Table II-6

DATES OF SALIENT CFC REGULATORY ANNOUNCEMENTS:

EPA, FDA, CPSC

Date	Content of Announcement	Agency	Federal Register
Nov. 7, 1976	Public hearings on substitute propellants.		41 FR 49574
Nov. 26, 1976	Proposed Labeling Requirement announced by FDA for the 80 percent of products (chiefly cosmetics and also medicine and food) under FDA jurisdiction.	FDA	
Jan. 5, 1977	Public hearings on substitute propellants.		42 FR 1066
Apr. 29, 1977	Final Labeling Requirement announced by FDA for the 80 percent of products (chiefly cosmetics and also medicine and food) under FDA jursdiction.	FDA	FR 22017, 4/29/77
May 13, 1977	Proposed timetable of phase-out: 1. Stop manufacture by 10/15/78 2. Stop distribution and processing by 12/15/78 3. Stop interstate shipments by 4/15/79.	EPA FDA CPSC	42 FR 24542, 5/13/77 42 FR 24536, 5/13/77 42 FR 24550, 5/13/77
Aug. 24, 1977	Final Labeling Requirement annnounced by CPSC for 13 percent of products (chiefly household products) under its jurisdiction. Effective date: 2/20/78.	CPSC	FR 42780-42784, 8/14/77
Mar. 17, 1978	Final Rules for the phase-out: 1. Stop manufacture of CFCs for nonessential aerosol uses by 12/15/78 2. Cease interstate shipment of CFCs, effective 4/15/79.	EPA FDA	43 FR 11318, 3/17/78 43 FR 11301, 3/17/78
Misc. Dates	Clarification of the rules.	EPA	Various dates from 1978 to the present
Oct. 7, 1980	Advance Notice of Proposed Rulemaking: "Ozone Depleting Chlorofluorocarbons; Proposed Production Restrictions."	EPA	45 FR 66726-66734

economic impact of regulation on producers of aerosol products and relevant chemicals? Its actions include the two Subcommittee hearings by Congress in late 1974 and early 1975; regulatory announcements in mid-1975 (IMOS); as well as actions by FDA, CPSC, and EPA in 1976. The prominent inaction of the Federal government was the decision not to deny the validity of the hypothesis about the effects of CFCs on the stratospheric ozone layer.

Because of the Congressional hearings and media events by 1975 and because of the 1976 labeling announcements by the Federal government, the 1978 date of the ban is not an appropriate initial date for impact analysis. To assess the sensitivity of this study to whether 1975 or 1976 should have been selected as the initial date, the economic impact of regulation is estimated separately using each. To simplify the text, the term "regulation" is used for the three sequential events that are synergistic in terms of their economic impact:

- The announcement of the ozone depletion hypothesis in June 1974
- The anticipation of regulation
- The regulation itself, which included a labeling requirement for products propelled by CFCs and then a ban on CFC use.

THE TERMINATION DATE

Some economic impact is already over in 1981, whereas other effects of regulation continue. The reformulation of products from those previously propelled by CFCs to alternative propellants, chiefly HCs, is an example of effects that are over. Marketers and fillers have largely completed these reformulations; the costs of reformulation are largely known; and consumers may choose between the reformulated products and nonaerosol forms of the same products.

Other aspects of economic impact can be evaluated in 1981, although their effects will continue for some time. One of these is the impact on capital, and the other is effects on consumer tastes.

Impact on Capital

1990 has been selected as a reasonable date on which to terminate economic impact on capital equipment that became unusable due to regulation. Impact continues to the extent that capital equipment was dedicated to specific aerosol or chemical use, became unemployed due to regulation, and could not be reemployed elsewhere.

The assumptions made by this study with respect to capital in the aerosol sector are:

- Plant and equipment in the aerosol sector (aerosol containers, valves, and filling) is dedicated and, therefore, can largely be used only in the production of aerosols; that is, the equipment cannot be converted to nonaerosol use without such substantial costs that one might as well start from scratch.
- That this equipment became partially unemployed -- and will continue to be so -- due to regulation.
- That the equipment had a remaining economic (functional) life extending until at least 1990.

Previous studies of CFCs have documented that equipment in the aerosol sector is dedicated. For example, the Commerce study [76] contains information on the impossibility of converting capital equipment in aerosol cans (p. 61) and in aerosol valves (p. 62). IR&T [36, p. 2-40] suggests filling equipment is largely dedicated. IR&T information can be supplemented by information in recent used equipment catalogues in which some aerosol fillers are offering their CFC filling equipment for sale.

The issue of the remaining economic life of the equipment is more difficult to document. It is concluded, however, that a precise estimate is irrelevant given the industry assumptions about the possibility of reduced impact by 1990 due to changes in consumer tastes with respect to aerosols (discussed below).

The chemical sector includes producers of CFCs and of precursor chemicals. In this sector, as well as the aerosol sector, the duration of economic impact continues until at least 1990 because of assumptions about capital. The assumptions are:

- Plants and equipment in the chemical sector can largely be used only in the production of specific chemicals affected by regulation. In the case of CFCs, equipment designed for the production of CFC-11 and CFC-12 is largely dedicated; that is, it cannot be converted to the production of other CFCs without virtually rebuilding the equipment.
- That this equipment became partially unemployed -- and will continue to be so -- due to regulation.
- That the equipment had a remaining economic life extending at least until 1990.
- Moreover, for some precursor chemicals economic impact is greater to the extent that there is equipment that produces co-products, only one of which is reduced by the CFC regulations.

Both the U.S. Deparment of Commerce [76] and Wolf [99] provide some documentation on issues related to the remaining economic life of capital equipment in the chemical sector. Wolf [99, pgs. 5 and 86] states that CFC-11 and CFC-12 equipment is largely dedicated.

> "CFC-11/CFC-12 ... plants are constructed for less stringent processing conditions and, therefore, they cannot, without virtually being rebuilt, be converted to produce CFC-113/CFC-114."

Moreover, she documents two other items: that plants have withdrawn from the market due to the aerosol ban,* and that demand for CFC-11 and CFC-12 will not reach (even) 1976 levels until at least 1990** due to aerosol regulations. The same conclusion about the difficulty of converting CFC-11 and CFC-12 capacity to other uses is also noted by the U.S. Department of Commerce [76, p. 30].

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*On page 28, Wolf says that there have been plant closings of "entire facilities" by DuPont, Allied, and Pennwalt, and that "Union Carbide recently discontinued direct CFC production." She attributes this to regulation with the statement: "The closings of these plants undoubtedly resulted from anticipation of the aerosol ban ...."

**The current industry view is that CFC-11 will not return to 1976 levels even by 1990 in any application now foreseen. CFC-12, on the other hand, may return to its 1976 levels by 1990, according to current industry views.

For precursor chemicals, the situation was not documented by previous investigators. They did explore the extent to which some precursor chemicals are produced for one use [Commerce and Wolf] and the extent to which each chemical has co-products [Wolf]. Within the constraints of this project, it is impossible to collect new data on the extent to which equipment in precursor chemicals is dedicated to one use and is affected by regulation. It is assumed -- in the absence of information to the contrary -- that equipment is dedicated.

The remaining issue is the extent to which capital equipment in the chemical sector has a remaining economic life. Industry views are that their equipment had a remaining life of at least 15 to 20 years in the absence of regulation.* This, in fact, is easier to document in the case of chemical producers than in the case of aerosols because the plant Pennwalt closed was relatively new and DuPont's Corpus Christi plant which manufactures carbon tetrachloride and tetrachloroethylene came on-line at about this time.** Moreover, Union Carbide was able to sell its CFC-22 plant that was 25 to 30 years old to International Plastics indicating the functional life of the plant could be expected to continue for some time.

Supplementary information on assumptions about capital is in Appendix D. One piece of information included there relates to capacity in CFC manufacturing, and the other, to capacity in the aerosol filling industry.

Impact on Consumer Tastes

Regulation also had an impact on consumer tastes with respect to aerosols. Consumers today continue to consider aerosols a less desirable method of dispensing active ingredients than they did prior to regulation.

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*CFC manufacturers, on average, stated equipment has an "indefinite" life, subject to small maintenance costs.

**The Corpus Christi plant was scheduled to integrate production facilities for CFC-11/CFC-12 and CFC-113/CFC-114, their raw materials (carbon tetrachloride and tetrachloroethylene, respectively) and facilities to utilize the by-products produced in the CFC plants. Due to the effects of the aerosol regulation, the CFC-11/CFC-12 plant was not built. As a result, carbon tetrachloride produced at Corpus Christi is shipped to existing CFC-11/CFC-12 plants. In essence, only a part of the Corpus Christi project was completed, and DuPont says this has resulted in an ongoing economic penalty from the ban to DuPont.

This study assumes that consumer tastes with respect to aerosols will change in the mid-Eighties and that by 1990, consumer tastes will return to their preregulation level. This is the industry hypothesis about consumer tastes. Since there is no basis for rejecting this hypothesis, it is accepted.

One should, however, point out some of the assumptions underlying this hypothesis. Among these are:

- Publicity regarding possible future regulatory action by EPA of nonaerosol uses of CFCs has no impact -- either positive or negative -- on consumer behavior.*
- Concern about the purported flammability of alternative propellants in alcohol-based products remains at present levels.**
- Any insurance issues, particularly for warehousing by wholesalers or retailers, are resolved without further impact.
- Nothing is found unsatisfactory about any of the techniques or chemicals that industry uses as flame suppressants.
- This study -- or any other study, here or abroad -- has no impact whatsoever on the aerosol industry, either positive or negative.

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*It should not, by definition of the ban. This is because aerosols, with the exception of a few essential-use exemptions to the ban, are no longer propelled by CFCs. But consumer confusion about propellants and environmental impact may remain.

**Chapter XII discusses the flammability of alternative propellants.

Chapter III

THE ECONOMIC IMPACT ON CONSUMERS

For consumers, the effect of a ban is to make a set of products unavailable that would have been available in the absence of regulation. The ban on CFC-propelled aerosols resulted in a reduction in the banned products from approximately 1.45 billion units in 1973 to almost zero units by the end of 1978. The significance of the loss of these banned products to consumers depends upon the relative price of substitute products, their availability, and their quality.

Three measures of the economic impact on consumers are examined in this chapter. They are: changes in prices before and after regulation, changes in quantities, and changes in quality.

Two topics that relate to the economic impact of regulation on consumers are discussed elsewhere. One is the loss in consumers' surplus as a result of the ban, which is discussed in Chapter XIII. The other is the comparative safety of alternative propellants in consumer use, which is discussed in Chapter XII.

In order to evaluate the impact of regulation on consumers, one must identify the major products that had to be reformulated from using CFCs to an alternative propellant. These were identified by an environmental criterion, namely, those products resulting in the largest purported CFC emissions into the atmosphere.* The two major products in this category are hairsprays and antiperspirants/deodorants (A/D). ADL [4, Table III-2]** provides the data for this selection.

According to ADL, hairspray contributed 35 percent of the total aerosol-related CFCs emitted into the atmosphere in 1973,*** and personal underarm deodorants and antiperspirants contributed 40.4 percent. This totals 75.4 percent of all aerosol-related emissions.* The product detail in the ADL table allows a listing of other product groups:

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*An environmental criterion is used because the purpose of regulation is to reduce the amount of CFC emissions into the stratospheric ozone layer. Since this is the objective of regulation, it is an appropriate criterion, albeit not the sole one. For the use of this criterion to select products for regulation, see the Canadian economic impact studies [15,16].

**IR&T [36] also used the ADL table.

***Technically, from an environmental point of view, information on the chlorine content of different CFC compounds (CFC-11, CFC-12, and CFC-114) or mixtures should be used to assess the effect on the stratospheric atmosphere. However, this refinement would not affect the choice of major aerosol products.

Medicinal and pharmaceutical	3.8%
Industrial products	3.3%
Other personal products except colognes and perfumes	3.1%
Insecticides	2.8%
Coatings	2.0%
Laundry products	2.0%
Colognes and perfumes	1.5%

Although the products to be studied are identified using an environmental criterion, major products requiring reformulation may also be identified using economic criteria, such as the value of shipments. The U.S. Bureau of the Census [80] provides data on the total value of shipments, in some cases by dispensing method, for a variety of product categories. These are summarized for personal products (SIC 2844) in Table III-1. Using this criterion, fragrances as well as hairsprays and A/D are classified as major products. However, the data necessary for the analysis of fragrances are not available.**

Yet another economic criterion for selecting major products is the criterion of the relative costs of reformulating aerosol products from CFCs to alternative propellants. (These costs are discussed later in an analysis of the economic impact of regulation on marketers, Chapter VII.) Among the most difficult products to reformulate were antiperspirants, colognes, spray cooking lubricants, and some industrial products.

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*Aerosol-related emissions were estimated to be 52 percent of total CFC emissions into the atmosphere in the United States in 1973.

**Information on fragrance prices, quality, and quantity are insufficient for the purposes of this study. Take, for example, the case of fragrance prices. Bureau of Labor Statistics (BLS) price data exists for fragrances in aerosol and nonaerosol form. The difficulty with using BLS data is that the aerosol product is not adjusted for changes in reformulation from CFCs to HCs. Time series on fragrance prices from other sources are unavailable.

Table III-1

VALUE OF SHIPMENTS OF SELECTED PERSONAL PRODUCTS

(Millions of 1977 Dollars)

Product	Value of Shipments[a]
Hairspray	
Aerosol	172.4
Nonaerosol	83.8
Antiperspirants/Deodorants	
Aerosol	311.7
Nonaerosol	210.5
Shaving Creams[b]	
Aerosol	80.4
Nonaerosol	15.8
Fragrances[c]	1,096.8

[a] Data collected for companies with sales of $100,000 or more a year.

[b] Shaving creams were not propelled by CFCs at the time of the announcement of the ozone depletion hypothesis.

[c] The fragrance (perfumes, colognes, toilet water) data are not broken down by delivery system, that is, aerosol vs. nonaerosol.

Source: Census [80].

This brief look at the selection of criteria suggests that one should concentrate on hairsprays and A/D since regulation was designed to reduce CFC emissions into the atmosphere and since their value of shipments and reformulations effort were large. In addition to the data problems with fragrances, no continuous historical time series of prices could be obtained for spray cooking lubricants, so these two products cannot be included in the analysis of impacts on consumers.

PRICE

Three measures of price are used for evaluating the economic impact on consumers of regulating aerosol uses of CFCs:

- The nominal price (the price index of an aerosol in current dollars)
- The real price (the price of an aerosol in constant dollars, defined as the nominal price index divided by the wholesale price index)
- The relative price (the ratio of the nominal price index of an aerosol product to the nominal price index of a nonaerosol product).

Price Indexes

Before making comparisons, it should be clear how the price indexes for hairsprays and A/D were constructed for this study. The procedures were similar to those of the Bureau of Labor Statistics (BLS). Suggested wholesale prices for various brands of each product were obtained and indexed so that 1967 = 100. An unweighted average of the individual indexes was calculated in order to obtain a price series for a single product (hairsprays or antiperspirants). In these two cases where products were reformulated, price indexes were also adjusted for the "equivalency" in the amount of active ingredient delivered per ounce of the two products before and after reformulation from CFCs to HCs. (For a more complete description of how these indexes were constructed, see Appendix A.)

One of the major problems in adjusting for equivalency is that each company made its own changes in active ingredients and solvents (including flame suppressants) as well as changes in propellants. Since this information is proprietary, it was necessary to use industry estimates of the average equivalency, as noted in Table III-2.

Table III-2

EQUIVALENCY BETWEEN PRODUCTS

Product	Range	Estimate Selected for Adjusting Price Data
Hairsprays	8-9 oz. of an HC aerosol is equal to 13 oz. of CFC-propelled aerosol	.654
Antiperspirants	3-4 oz. of an HC aerosol is equal to 8 oz. of a CFC-propelled aerosol	.438

Source: Industry.

Another major problem with any price index of this sort is that it is unclear how many products are actually sold at their suggested wholesale or retail price. The assumption made here is that products sell at wholesale list price. This is a strong assumption, given the widespread discounting of the prices of hairsprays and A/D that reportedly* occurs in practice.

The nominal, real, and relative price indexes for hairsprays and A/D, 1970 through 1979, are summarized in the next seven graphs. On the basis of these graphs, several conclusions have been reached about the behavior of prices for these products in the Seventies. The most important are:

- o Nominal Prices, by Product (Graphs III-1 and III-2). Conclusions about the prices of hairsprays and A/D partially depend on whether or not one adjusts for the fact that two different sized cans, one propelled by CFCs and the other by HCs, yield the

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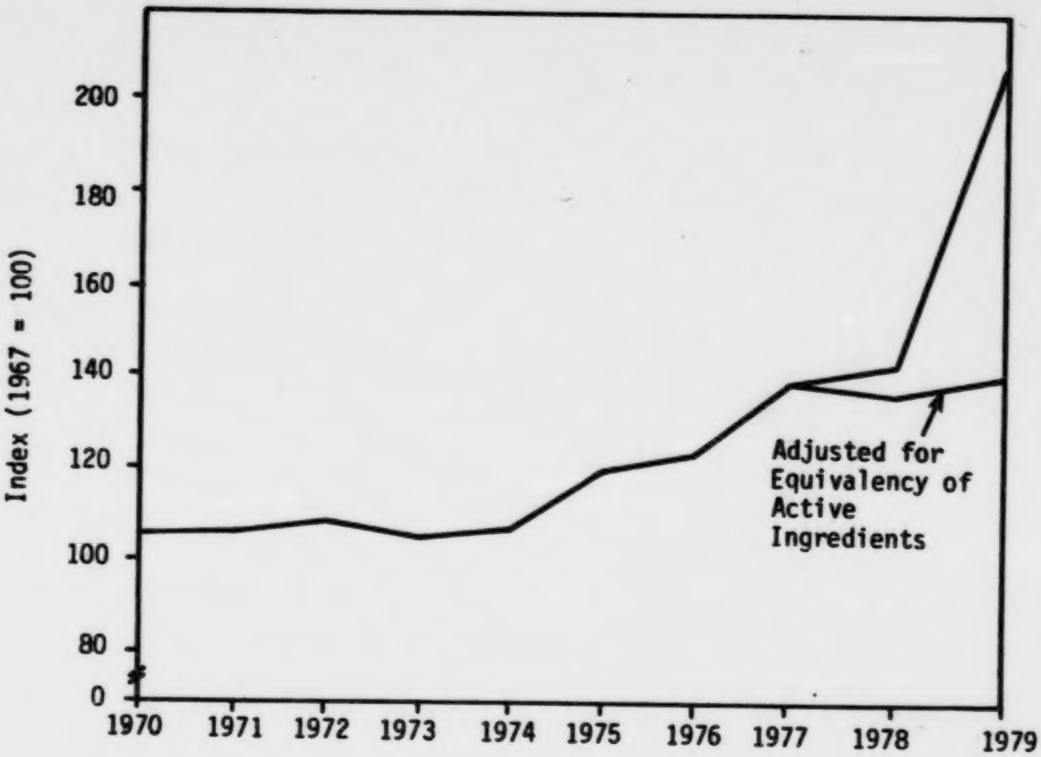
*Source: Chemical Marketing Reporter.

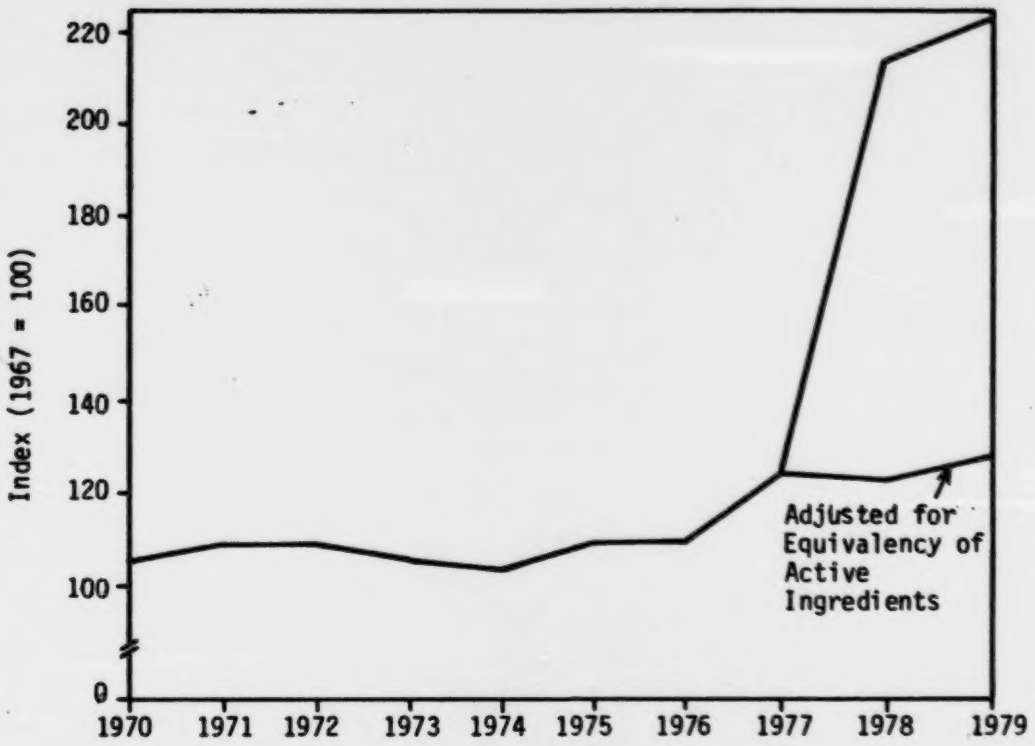


Graph III-1. Nominal Price of Aerosol Hairsprays, 1970 to 1979 (An Unweighted Average).

Sources: Redbook [45] and transformations. See Appendix A.

same amount of active ingredient. Using the adjusted figures, the graphs indicate that there were no substantial increases in prices as a result of reformulation. Stated differently, without this adjustment, it incorrectly appears as though nominal prices rose substantially due to reformulation.

- Nominal Prices, by Brand (Graphs III-3 and III-4). Nothing conclusive can be said about whether the nominal price of hairsprays and A/D rose, remained constant, or fell after reformulation; the behavior of prices of individual brands exhibits no consistent patterns. Of the four brands whose suggested wholesale prices were tracked over time, some rose, some remained constant, and some fell after reformulation, which was completed in

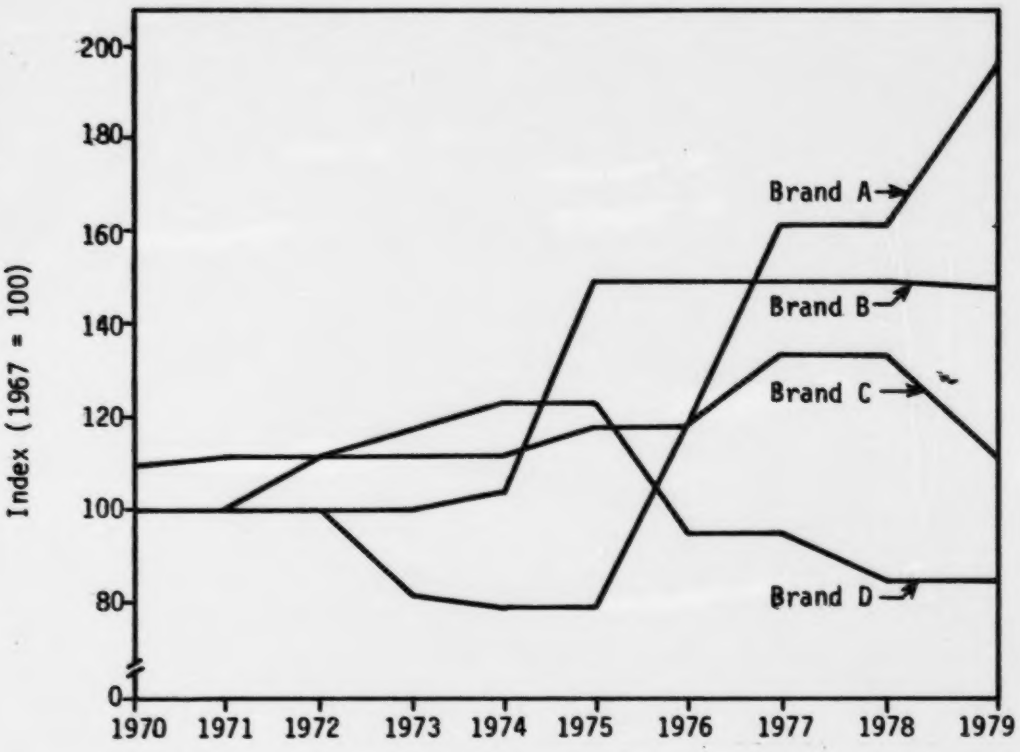


Graph III-2. Nominal Price of Aerosol Antiperspirants, 1970 to 1979 (An Unweighted Average).

Sources: Redbook [45] and transformations. See Appendix A.

1977 in anticipation of the ban. Moreover, there is no reason for accepting or rejecting the observations of any of the brands.

- Real Prices (Graphs III-5 and III-6). The real price (the nominal price index divided by the BLS wholesale price index) of each aerosol product declined dramatically between 1972 and 1974 -- a decline that began in the early Sixties. In 1977, the year in which reformulations were completed, the real price of aerosol hairsprays and A/D rose, only to decline somewhat in 1978 and 1979.
- Relative Prices (Graph III-7). There is no continuous price series data for nonaerosol hairsprays. Therefore, only information on A/D is presented. The price of an aerosol A/D fell relative

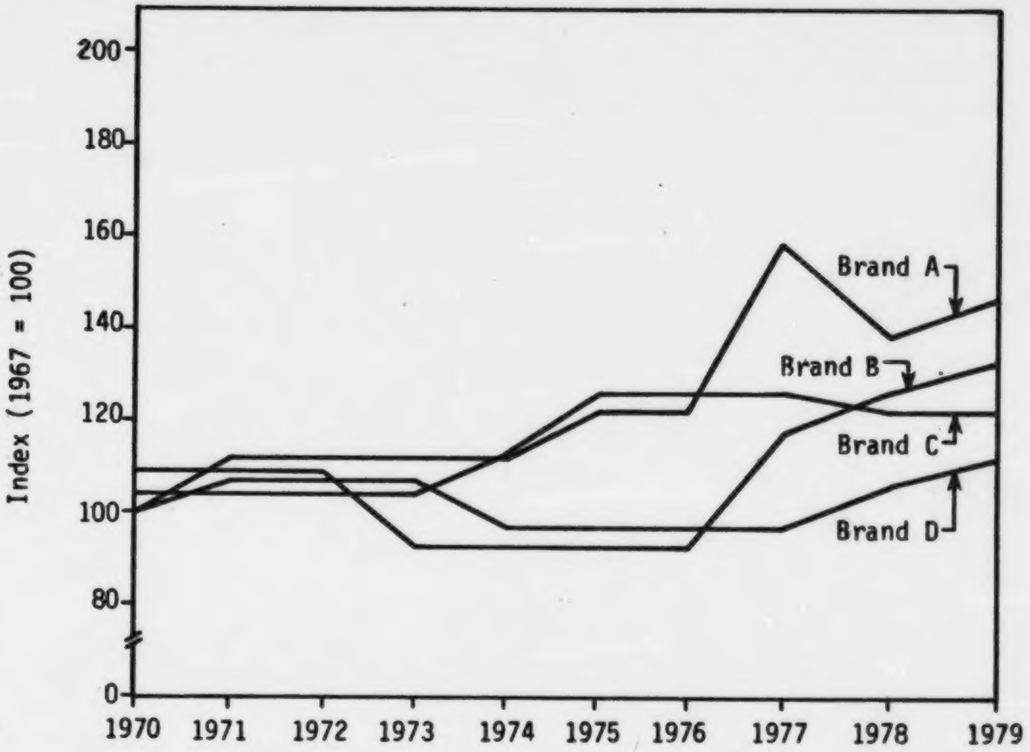


Graph III-3. Nominal Price for Four Aerosol Hairsprays, 1970 to 1979 (Adjusted for Equivalency).

Sources: Redbook [45] and transformations. See Appendix A.

to the price of a nonaerosol A/D beginning in 1973, leveled off in 1977, and then continued to decline in 1978 and 1979.

The graphs suggest that there was no reduction in prices attributable to the ban. Regulation had no impact on prices except in 1977 when marketers were reformulating their products in anticipation of the 1978 ban. In 1977, nominal and real prices rose, and relative prices remained constant. Whether the price declines of 1978 and 1979 would have occurred in the absence of reformulation cannot be evaluated, because the long-run trend in real prices, which had begun in the early Sixties, was steadily downward.



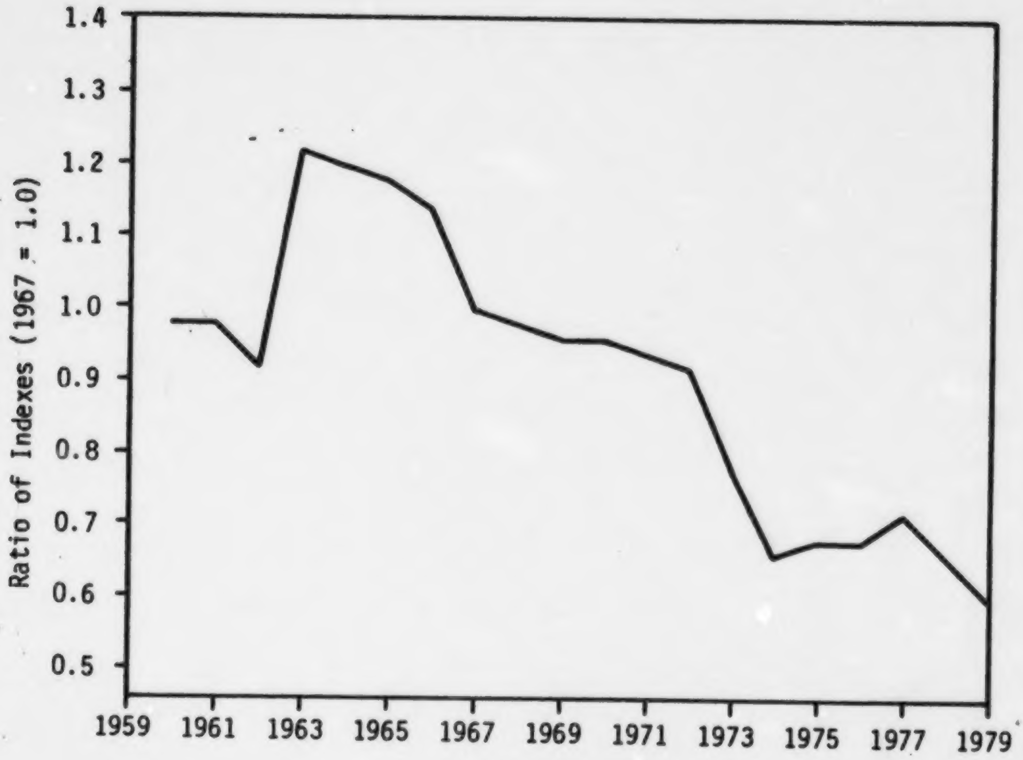
Graph III-4. Nominal Price of Four Aerosol Antiperspirants, 1970 to 1979 (Adjusted for Equivalency).

Sources: Redbook [45] and transformations. See Appendix A.

QUANTITY

The economic impact of regulation on consumers can also be estimated by examining changes in the number of products available before and after regulation. To the extent that consumers have a wider choice in either the number of aerosol or nonaerosol forms of dispensing a product today than prior to regulation, for example, the aerosol regulations have had a positive effect on consumers.

In principle, doing a product count requires collecting pre-ban information on every product previously propelled by CFCs and marketed in aerosol and nonaerosol form. In order to compare the pre-ban and post-ban range of choices, the following information is also needed:



Graph III-5. The Real Price of Aerosol Hairsprays, 1960 to 1979.

- All brand names related to the generic product before and after regulation; in the major categories in this study, there is often a very large number of brand names.
- All packaging forms for aerosols, by propellant; for nonaerosols, by packaging method, for each brand.

The totals by product for, say, 1972, could then be compared with those of 1979. This approach was impossible within a reasonable time constraint.*

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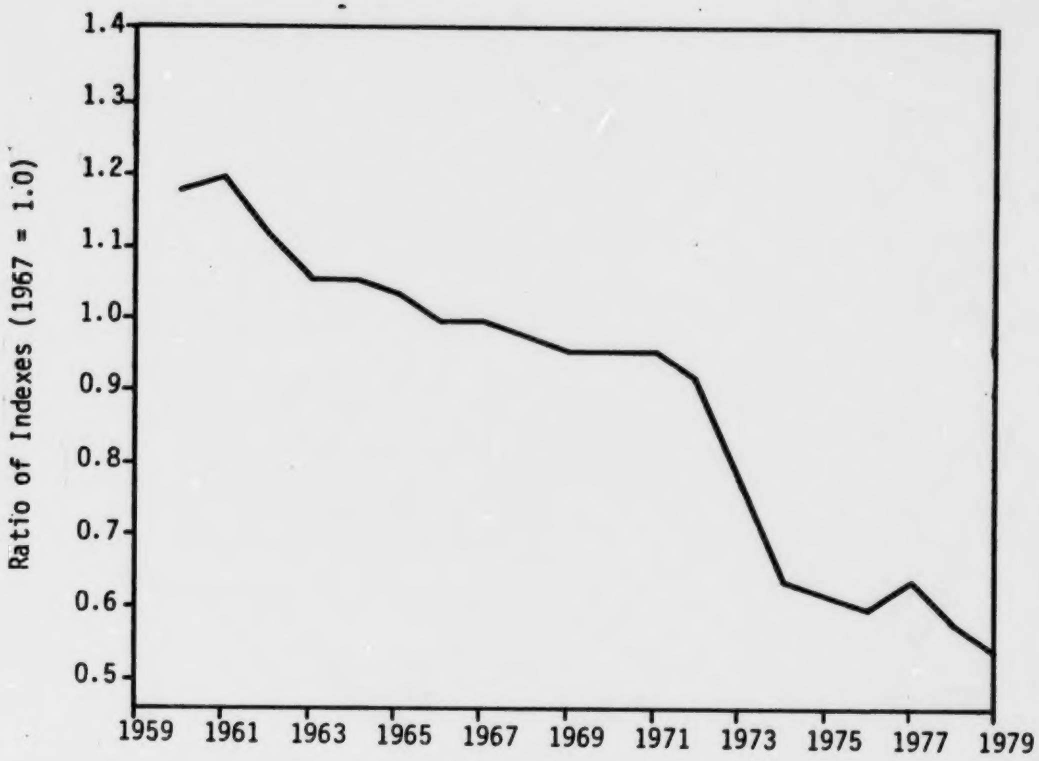
*This information seems to be routinely collected for only one industrial sector -- the fragrance industry. The "Fragrance Directory" lists fragrances by brand name, size, suggested retail price, and packaging method. There are hundreds of choices available. However, such lists are never exhaustive; they tend to be drawn up for (and with the help of) members of the trade association preparing the directory. Data from nonmembers or nonrespondents is not usually included.



Graph III-6. The Real Price of Aerosol Antiperspirants/Deodorants, 1960 to 1979.

As a result, this study estimated changes in quantity only for major brands of the chief products affected by the ban, namely, hairsprays, antiperspirants, and deodorants. This question was posed: Did consumers of the major brands of each product have more choice in their packaging form in 1979 than they did in 1972? The selection of "major" brands was made by using surveys and industrial estimates.* The sources for the availability of substitutes were the Bluebook [2] and Redbook [45] of pharmacists. Brands are identified as "A", "B", etc.**

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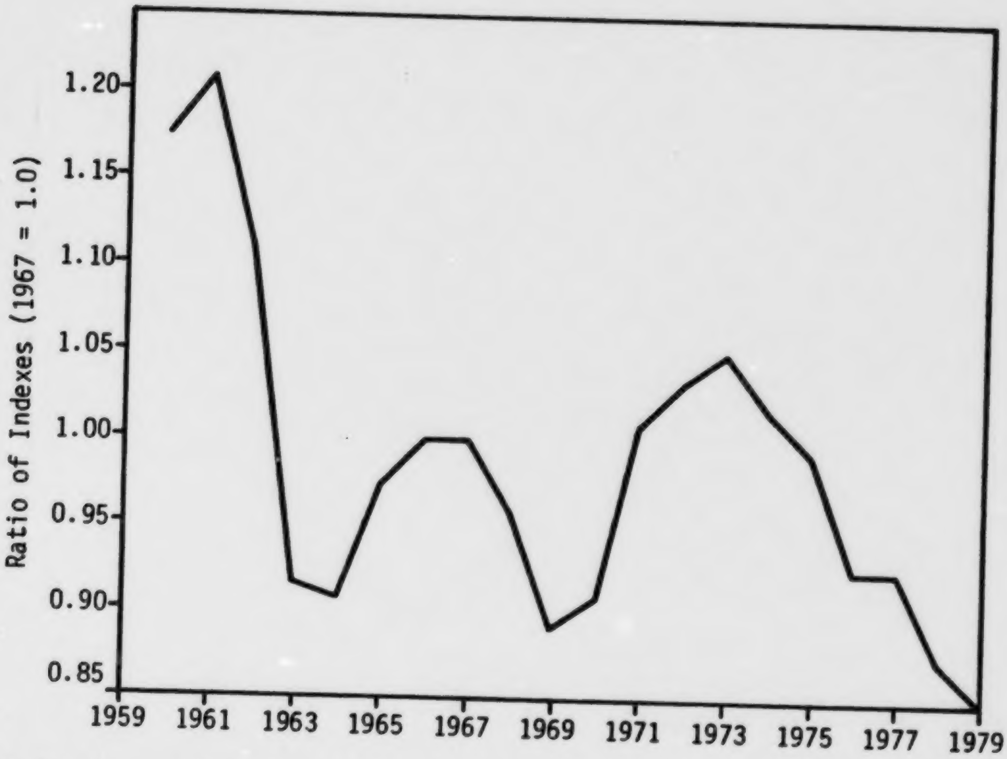
*Two surveys exist that identify major brands: the 1971 DuPont survey, no longer available, and a recent hairsprays survey by Parents Magazine [60]. Industry estimates that these seven to nine brands represent about 90 percent of annual sales for these products.

**There is no relationship between the identification of a brand as "A" in this section on quantity and the previous section on prices.



Graph III-7. The Relative Prices of Aerosol to Nonaerosol Antiperspirants/Deodorants.

The results, shown in Tables III-3 through III-5, indicate an increase in the range of choice in nonaerosol products. Consumers have more choices in nonaerosol forms of the same brand-name products today than in 1972. Since this increase in the number of nonaerosol products can reasonably be attributed to regulation, the effect on quantity is a positive benefit of regulation although it cannot be given a monetary value.

QUALITY

A change in the quality of aerosol products is a third measure of the economic impact of regulation on consumers. Perceptions of quality changes by consumers as a result of regulation are evaluated by studying consumers'

Table III-3

THE NET INCREASE IN PACKAGING METHODS FOR HAIRSPRAYS

Brand	1972		1979		Net Increase in 1979
	Aerosol	Nonaerosol	Aerosol	Nonaerosol	
A	X		X		0
B	X		X	X	1
C	X		X	X	1
D	X		X	X	1
E	X		X		0
F	X		X	X	1
G	X		X	X	1
H	X		X	X	1
I	X		X	X	1
Total	9		9	7	7

Sources: Surveys of consumer products [27,28,60], and the Bluebook [2] and Redbook [45] of pharmacists.

Table III-4

THE NET INCREASE IN PACKAGING METHODS FOR DEODORANTS

	1972		1979		Net Increase
Brand	Aerosol	Nonaerosol*	Aerosol	Nonaerosol*	in 1979
A	1	3	1	3	0
B		2		3	1
C	1	1	1	3	2
D	1	4		6	1
E	1		1	3	3
F	1	3	1	3	0
G	1	0	1	1	1
Total	6	13	5	22	8

*The packaging methods for nonaerosols include creams, pumps, roll ons, sticks, push buttons, sprays, squeeze, solids, and other.

Sources: Surveys of consumer products [27,28,60] and the Bluebook [2] and Redbook [45] of pharmacists.

Table III-5

THE NET INCREASE IN PACKAGING METHODS FOR ANTIPERSPIRANTS

	1972		1979						
Brand	Aerosol	Roll On	Aerosol	Roll On	Solid	Stick	Pump	Other Nonaerosol	Net Increase in 1979
A		X		X	X			2	3
B	X		X					X	1
C	X	X	X	X	X	X			2
D	X		X	X			X		2
E	X		X						0
F	X		X	X					1
G	X		X						0
Total	6	2	6	4	2	1	1	3	9

Sources: Surveys of consumer products [27,28,60] and the Bluebook [2] and Redbook [45] of pharmacists.

revealed preferences.* This method involves an analysis of consumers' actual buying behavior with respect to aerosol and nonaerosol products before and after regulation. Inferences are drawn about how consumers evaluate the effects of a regulation by examining these purchasing patterns. After studying revealed preferences, the reasons for these changes can be explored.

In this report, actual total sales of hairsprays and A/D, by two packaging forms (aerosol and nonaerosol), before and after regulation are compared. If the market shares differ after regulation, consumers have revealed a change in their net preferences for one packaging form over another. For example, if there is increased use of aerosol deodorants relative to nonaerosols after regulation, compared with preregulation usage, it would be reasonable to conclude that consumers perceive that aerosols have become more desirable than nonaerosols as a result of the announcement of the ozone depletion hypothesis and of government regulations. If the shares purchased are constant, quality has not changed. If the relative share of aerosol deodorants has declined, consumers have revealed that they consider aerosols to be of a lower quality.

For hairsprays and A/D, a variety of information is available on changes in the shares of aerosol relative to nonaerosol purchases made by consumers.** The results of a Nielsen survey [53] and of an analysis of Towne-Oller data [73] are included here in Graphs III-8 through III-11. In each case, there is a continual decline in the share of aerosol purchases since 1974.

There remains the issue of why consumer tastes shifted from aerosols to nonaerosols. This "why" -- answers to which are suggested here -- is both critical and arguable. The information needed to resolve this issue is year-by-year surveys of consumer attitudes with respect to aerosols. Such surveys

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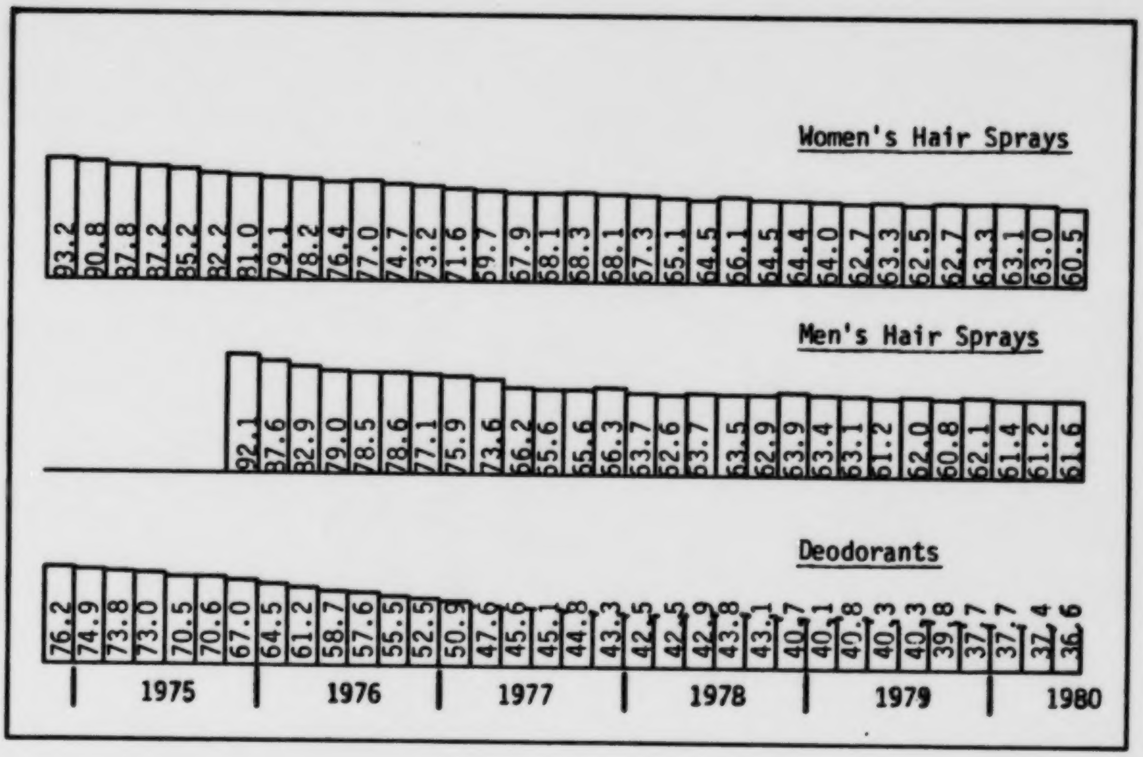
*For a brief discussion of the theory of revealed preference, see Henderson and Quandt [34]. For a recent summary of some of the uses of the technique for assessing the benefits of environmental regulation, see the Massachusetts Institute of Technology's Center for Policy Alternatives Report to Congress [74].

**Among these are The Census of Manufactures, available only for 1967, 1972, and 1977 (the Census years); a Nielsen survey of purchases in three types of outlets; Towne-Oller data based on 25 percent of retail food store sales; and other surveys that marketers pay for and use to make marketing decisions. These other surveys cannot be cited or referenced.



Graph III-8. Share of Aerosol to Nonaerosol Hairsprays and Deodorants, 1974 to 1980.

Source: A. C. Nielson Company [53].

would list and rank consumers' reasons for their choice of an aerosol versus a nonaerosol. These annual surveys do not exist.

In the absence of annual surveys, one can develop plausible explanations for the shift in consumer preferences from scattered information:

- o Consumers were concerned in 1975 and 1976 that some aerosols destroy "ozone" and that the Federal government agrees with this scientific conclusion. This tie-in between aerosols and environmental concerns was reported in two one-time consumer surveys, one by CPSC and the other by DuPont.*

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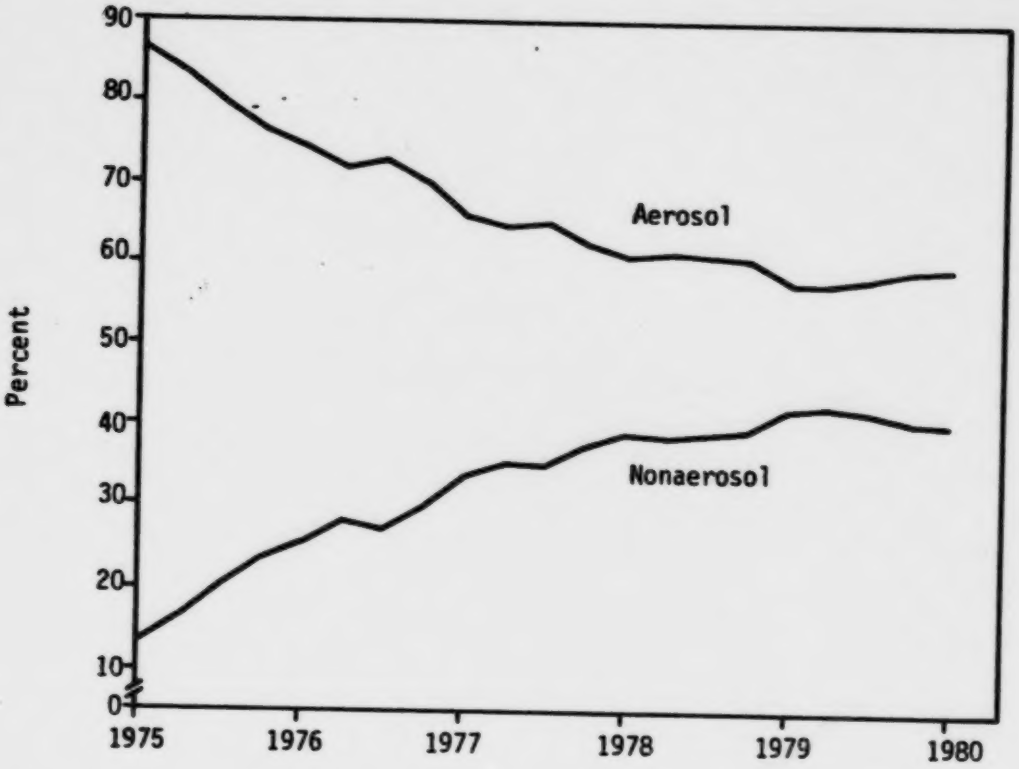
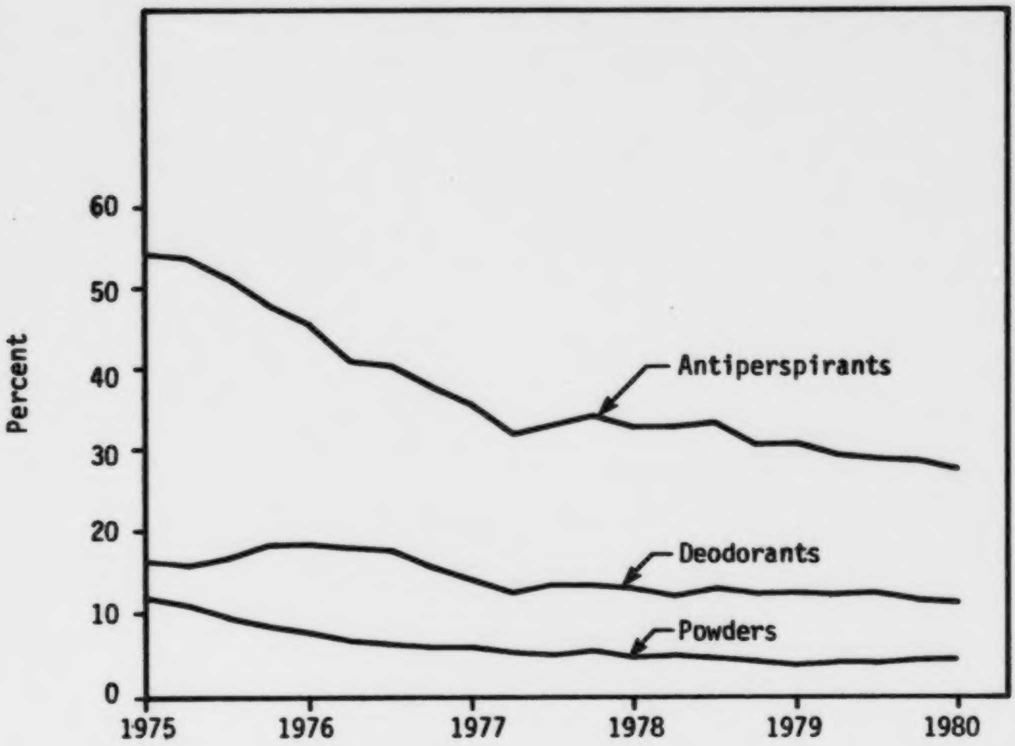
*Source: Schiff [69]. We have seen neither survey, although there are newspaper accounts of the CPSC telephone survey. DuPont's survey is no longer available.



Graph III-9. Quarterly Behavior of Hairsprays: Dollar Volume Shares, 1974. Sources: Towne-Oller [73] and transformations.

- o Marketers fund and presumably use the sales data -- Towne-Oller's, Nielsen's, and others such as that cited in Aerosol Age, December 1980 [67] -- in making decisions about the forms in which to package products and how to allocate research and development (R&D) and advertising budgets between aerosol and nonaerosol products.
  - The increased advertising for nonaerosols relative to aerosols reinforces the trend away from aerosols to nonaerosols, because advertising affects consumer tastes.
  - More R&D is said to have been spent on formulating and packaging nonaerosols in recent years.
- o Individual brand information indicates that a few companies have purportedly received, in the last three years, fifteen to



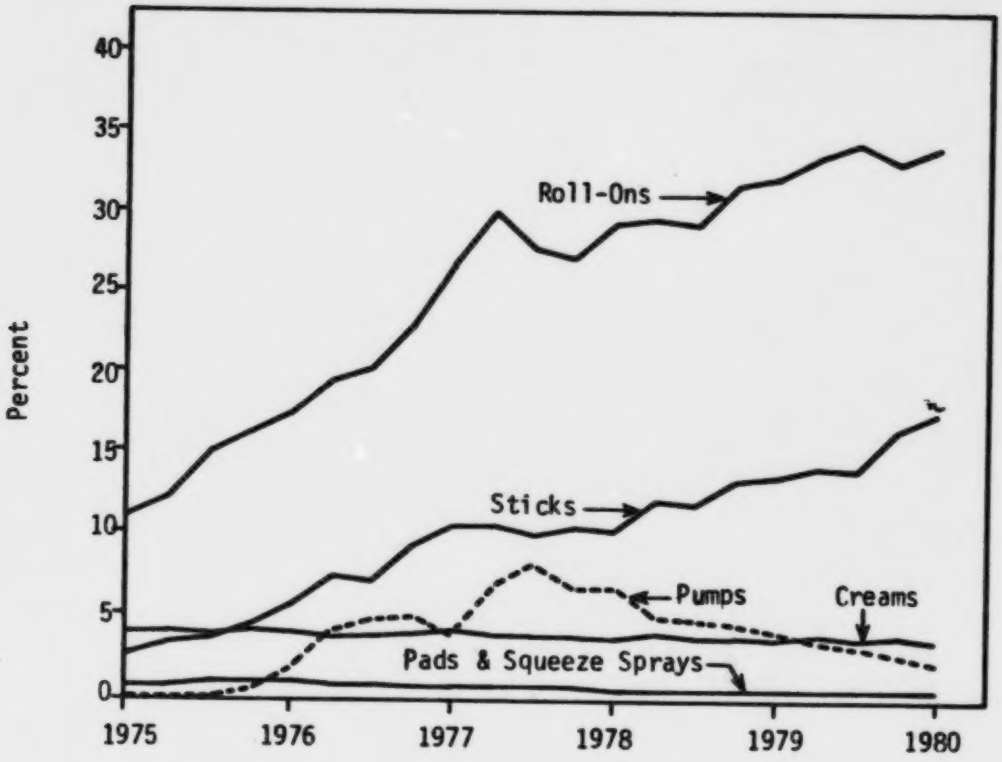
Graph III-10. Quarterly Behavior of Aerosol Deodorants and Antiperspirants: Dollar Volume Shares, 1974 to 1980.

Sources: Towne-Oller [73] and transformations.

twenty times as many complaints for household products packaged in aerosol, rather than nonaerosol, form. In these cases, the ingredients and solvents were the same, the only difference was that one of the products had a propellant.

- Consumers may have reacted to reports of the increased flammability of the new HC-propelled hairsprays and A/D relative to the previous CFC-propelled products by not buying as many of the new HC, alcohol-based products. For a discussion of patterns in injury rates in consumer use of aerosols in the Seventies, see Chapter XII on safety in this report.

Although it is somewhat difficult to develop the reasons for this change in consumer tastes from aerosol to nonaerosol products, it is impossible to completely separate the part of these changes that were due to the



Graph III-11. Quarterly Behavior of Nonaerosol Deodorants and Antiperspirants: Dollar Volume Shares, 1974 to 1980.

Sources: Towne-Oller [73] and transformations.

actions or inactions of the Federal government from those due to nonregulatory factors. This is because the announcement of the ozone depletion hypothesis, the anticipation of regulation, and the regulations themselves were synergistic in terms of impact as noted in the previous chapter on the dating of impact. It is reasonable, however, to attribute most of the decline in product quality to regulation. This loss to consumers due to decreased product quality -- like the gain to consumers in nonaerosol quantities -- cannot directly be assigned a dollar value. Indirectly, it is approached by considering the loss in consumers' surplus due to regulation, a topic considered in Chapter XIII.

Essential-Use Exemptions

The quality of some aerosol products has remained constant due to regulation, since a limited number of exemptions for essential uses have been provided by the EPA.* In essential-use cases, aerosols propelled by CFCs remain available. (Thus, CFC propellant use has not decreased to zero as a result of regulation.) The exemptions to the ban, effective June 1980, are as follows:

- Mercaptan stench warning devices
- Release agents for molds used in the production of plastic and elastometric materials
- Flying insect pesticides for use in nonresidential food handling areas and for space spraying of aircraft
- Diamond-grit spray
- Nonconsumer articles used as cleaner-solvents, lubricants, or coatings for electrical or electronic equipment
- Articles necessary for safe maintenance and operation of aircraft
- Uses essential to the military preparedness of the United States as determined by the Administrator of the EPA and the Secretary of Defense.

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*Some essential-use exemptions are explicitly listed in the CFC ban regulations. In addition, a firm may formally request an exemption from EPA. The process EPA uses in evaluating applications for an essential-use exemption is described in "Essential-Use Determination - Revised," a support document to the March 17, 1978 rule. In making these determinations, EPA considers the availability or nonavailability of substitutes, the possibility of severe economic hardship if the use of CFCs is not allowed, and the health and environmental consequences of use of another product in place of CFCs.

Chapter IV

ECONOMIC IMPACT ON PRODUCERS: INTRODUCTION

An aerosol product consists of one or more active ingredients, as well as inert ingredients such as solvents, which are dissolved or suspended in a propellant and sealed under pressure in a container. These propellants are either liquified gases such as CFCs and HCs, or compressed gases such as carbon dioxide.

CFCs are organic chemical compounds consisting of chlorine, fluorine, carbon, and (sometimes) hydrogen. They are used in aerosol products because of their low flammability, chemical stability, low toxicity, inertness, and a variety of other properties that aid the formulation of aerosol products. CFC propellants do not interfere or react with the active ingredients in aerosol products; they reduce or eliminate flammability hazards of other formulation components, and they readily supply the range of spray characteristics desired. Prior to 1974, these advantages were offset by the higher cost of CFCs relative to HCs, the chief alternative propellant.

Thus, before 1974, CFCs were primarily used in products where the fire retardant property of their inertness was viewed as being of critical importance, whereas HCs were the chief propellant in aqueous-based products in which flame suppressant features were less important. CFCs were the primary propellant in pan sprays, pharmaceutical products, some industrial products, and in most alcohol-based personal products (hairsprays, antiperspirants, deodorants, and colognes). HCs were used in water-based aerosol products such as shaving lathers, window cleaners, spray starches, room deodorants, and space insecticides.

A small number of aerosol products (5 to 10%) are propelled by compressed gases in contrast to CFCs or HCs. Compressed gases have a major advantage over other propellants in low-temperature situations and are also nonflammable and inexpensive. The difficulty with compressed gases as propellants is that they produce a coarse spray and uneven pressure characteristics over the lifetime of the product. As a result, compressed gases are chiefly used in automotive products (including windshield de-icers and tire traction sprays) and some industrial products.

The chief industrial sectors affected by the regulation are:

- The chemical sector
- The aerosol sector
- The marketers of the aerosol products.

The chemical sector is comprised of companies, generally large firms, that manufacture CFCs and companies that supply basic chemical ingredients for their manufacture. Basic chemicals include hydrofluoric acid, carbon tetrachloride, fluorspar, sulfuric acid, sulfur, chlorine, methane, propylene, and carbon disulfide. Currently four of the five domestic producers of CFCs supply the remaining aerosol market for the small number of essential-use exemptions.

The aerosol sector is comprised of companies that produce metal and glass aerosol containers and valves, and companies that assemble and fill containers with propellant and concentrate (active ingredient and a solvent).

A marketer distributes (markets) a particular brand of a product -- a hairspray or antiperspirant, for example -- and is ultimately responsible for the specific formulation of that product. Products which had been propelled by CFCs had to be reformulated to alternative propellants, a complicated process which required altering all the chemicals (active ingredients, solvents, and propellants), as well as selecting suitable new valves and containers.

The loss in social welfare that is attributable to lost production by producers from their extant capital is calculated in this part of the report.* The reasoning behind these calculations can be explained.

When CFC aerosol production was regulated and before any resources were transferred from these sectors to the rest of society, net national product was reduced by the value of output in the aerosol and chemical sectors. By the national income accounting identity, net national product is equal to the net income of consumers and the revenues of government (recognizing that the retained earnings of corporations are ultimately income of owners of corporations, and neglecting for the present purposes foreign transactions). Hence, the income of households (and government) was reduced by the value of output that was lost in the aerosol and chemical sectors as the result of regulation.

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*The loss in social welfare due to the loss in consumers' surplus is discussed in Chapter XIII.

Some resources that were used in the production of aerosol products could be shifted to the rest of the economy. It is assumed that all labor and raw materials used in CFC aerosol production could be utilized elsewhere in the economy without any reduction in their marginal productivities. Capital equipment employed in CFC aerosol production, on the other hand, is assumed to be dedicated and to become partially unemployed. Consequently, profit-type income that would have been generated by this capital equipment in the absence of regulation did not get generated, thereby reducing net national product by the amount of its potential contribution. By the argument outlined in the preceding paragraph, this leads to the reduction of income for households (and government). Since the income of consumers has been reduced, social welfare must have declined.

It should be noted, of course, that capital equipment has a finite economic life, and, therefore, the economic cost of the ban declines over time. It is estimated that the economic life of the equipment would have expired around 1990, and with it, the economic cost of regulation attributable to lost production.

The economic impact of regulation on producers is evaluated in Chapters V through VIII, using several measures of economic impact. Among these are:

- Estimates of quantities lost due to regulation in the aerosol and chemical sectors -- that is, the difference between demand with regulation and demand without regulation. This topic is examined in Chapter V.
- Estimates of lost profits resulting from these lost quantities, that is, the net present value (NPV) of producers' profit streams foregone due to regulation. These results are found in Chapter VI.
- Estimates of some of the costs of regulation to marketers (Chapter VII) and custom fillers (Chapter VIII). Two of these costs are the once-and-for-all costs of reformulating products from CFCs to alternative propellants and the initial costs of

converting capital equipment. The economic impact of regulation on marketers (about 500 companies) is evaluated separately from the chemical and aerosol sectors because the strong presumption is made that losses due to aerosol sales to marketers were offset by their gains from nonaerosol sales.

In addition, there is supplementary information in Chapter IX on the economic impact of regulation on capacity, capacity utilization, investment, concentration, and profit rates. Among the methodological factors discussed in each chapter are the assumptions used and the basis for each, the procedures used and why, the extent to which there are nonquantifiable aspects to a particular measurement problem, and the limitations of the study.

Chapter V

ECONOMIC IMPACT ON PRODUCERS' QUANTITIES

Estimates of the quantities of aerosols and chemicals which were not produced due to regulation, but which would have been produced had there been no regulation are critical data for evaluating the economic impact of regulation on producers. To the extent that information about estimated quantity losses can then be combined with price and profit data, one can quantify economic impact on producers in monetary terms.

One set of estimates of quantity losses involves the three aerosol sectors: filling, containers, and valves. Data are available on the actual quantities of aerosol units filled, by product. Since every aerosol that is filled requires a container and a valve, demand for the products of each of these three sectors is identical. Estimates of this demand in the absence of regulation are made using statistical techniques and preregulation data. Once this is done, demand with regulation is subtracted from demand without regulation to obtain quantity losses due to regulation from the aerosol sector.

Estimates of the quantities lost due to regulation by the aerosol sector are an important component in an analysis of the losses in the chemical sector. The estimate must, however, be supplemented by a judgment of how much CFCs would have declined in use as aerosol propellants even in the absence of regulation. The relevant question is: To what extent would alternative propellants -- chiefly HCs -- have made inroads into the market share of CFCs in the absence of regulation?

Once the demand for CFCs with and without regulation is estimated, it is primarily a mechanical exercise to estimate quantity losses due to regulation for those chemicals that are precursors (feedstocks) of CFCs. This is due to the nature of the chemical process, in which the quantities of each chemical have a fixed relationship to each other.*

This section of the report is divided into three parts. These are:

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*Wolf [99] and Palmer [59].

- Quantity losses due to regulation for the aerosol sector, 1975 to 1979
- Quantity losses due to regulation for the aerosol sector, 1980 to 1990
- Quantity losses due to regulation for the chemical sector, 1975 to 1990.

Of these three topics, the greatest research effort was devoted to estimating the impact on aerosol producers in the period from 1975 through 1979. The approach is econometric, that is, it involves the use of statistical methods to extract as much information as possible from available economic data. The results of the statistical approach are supplemented by additional information in order to reach more plausible conclusions about demand in the absence of regulation and, therefore, quantities lost in the aerosol sector. The other two sections employ less formal techniques.

THE AEROSOL SECTOR, 1975 TO 1979

The assessment of the quantities lost in the aerosol sector as a result of regulation is done in two stages: for the historical period 1975 to 1979, and for the forecast period 1980 to 1990. In order to determine the lost quantities for 1975 to 1979, demand equations are estimated for aerosol products, by product category, for 1960 to 1974.

The results of these estimates are used to predict what demand in the absence of regulation would have been from 1975 to 1979. The advantage of estimating demand for individual product categories rather than for the aggregate (all aerosols) is that one can better evaluate the results.

The procedures and results of this study are comparable with those of previous studies of CFCs in which statistical methods were employed: d'Arge [24], Bailey [8], and IR&T [36].*

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*All three seem to have used the d'Arge estimates. d'Arge and Bailey are each authors of two of the three benefit/cost assessments of regulating CFCs that are included in an NAS report [51]. IR&T was the economic support document for the ban on the use of CFCs as aerosol propellants.

The Demand Equation

The per capita demand for a commodity is a function of three factors, other things being equal.* These are:

- The real "own" price of the product, that is, the price of the aerosol product relative to the general price level in the economy as a whole
- The real price of substitute products, that is, the price of the substitute nonaerosol product relative to the general price level in the economy as a whole
- Real disposable personal income per capita.

The equations are specified in logarithmic form:

$$QPC = a(PAR)^b\ (PNR)^c\ (YPC)^d\ e^r \tag{1.0}$$

where QPC = the per capita demand for an aerosol product
PAR = the real price of the aerosol product
PNR = the real price of the substitute, nonaerosol product
YPC = real disposable income per capita.

A log specification is used for two reasons: one, graphical evidence suggests that at least the income variable is usually logarithmically related to the dependent variable; and two, elasticities can be interpreted directly.

The specification of equations for purposes of statistical estimation differs from the general one described above, although the two are mathematically equivalent.** For the statistical estimation of the demand equations, a relative price term is substituted for the real price of the substitute product in order to allow a direct evaluation of the effects of changes in the relative prices of aerosol and nonaerosol products on per capita demand for aerosols.

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*For a discussion of these propositions, see any standard economics text, such as J. S. Cramer [22], or Henderson and Quandt [34].

**See Equations 3.0 through 3.2 for the proof of the mathematical equivalency of the two ways for estimating demand.

The specification can be illustrated for one product category: A/D. The equation that has been estimated is:

$$\ln(\frac{QAD}{Popu}) = \alpha\ln(\frac{PAD}{PND}) + \beta\ln(\frac{PAD}{WPI}) + \gamma\ln(\frac{Y_{\$72}}{Popu}) + r \qquad (2.0)$$

where QAD = the output of aerosol A/D in millions of units filled

Popu = the estimated U.S. population, in millions of people

PAD = an unweighted average of the suggested wholesale price of four major A/D marketed in aerosol form in the U.S., indexed so that 1967 = 100

PND = an unweighted average of the suggested wholesale price for major nonaerosol A/D, indexed so that 1967 = 100

WPI = the wholesale price index for all producer products, where 1967 = 100

$Y_{\$72}$ = real disposable income in the U.S. (in 1972 dollars)

α, β, γ = constant coefficients estimated by statistical techniques.

All equations are estimated for the historical period, 1960 to 1974. Because data are available only yearly for the dependent variable (the quantity of aerosols filled), all equations are estimated with only annual observations. Thus, there are at most 14 degrees of freedom.

Equations 1.0 and 2.0 are mathematically equivalent, although the signs of the two price terms must be interpreted correctly in order to evaluate the results. Take the case of A/D, where the notation is identical to that in Equation 2.0. Take the two price terms: $\alpha\ln(PAD/PND)$ and $\beta\ln(PAD/WPI)$. The answer is that the own price elasticity is $(\alpha + \beta)(\ln PAD - \ln WPI)$, and the substitute price elasticity is $(-\alpha)(\ln PND - \ln WPI)$.

This can be seen from rearranging terms and adding and subtracting the quantity $\alpha(\ln WPI)$:

$$\alpha(\ln PAD - \ln PND) + \beta(\ln PAD - \ln WPI) \qquad (3.0)$$

$$(\alpha + \beta)\ln PAD - (\alpha + \beta)\ln WPI - \alpha(\ln PND) + \alpha(\ln WPI) \qquad (3.1)$$

so that

$$(\alpha + \beta)(\ln PAD - \ln WPI) - \alpha(\ln PND - \ln WPI) \qquad (3.2)$$

Thus, to obtain the real "own" price elasticity, one sums estimates of $(\alpha + \beta)$. The real price elasticity of the substitute product is $-\alpha$.

Comparison with Previous Studies. The specification of these equations differs from previous EPA contractors working on CFCs in that the dependent variable is estimated on a per capita basis. The scaling by population of both the income variable (which they did) and the quantity variable (which they did not) is preferable. d'Arge's decision to use a linear specification, compared with the logarithmic specification used in this study, is not important.

The choice of a price variable differs from those of previous EPA contractors working on CFCs. There is no reason to believe that the price variables used by previous EPA contractors, which are based on average prices paid,* are any better or worse than those used in this study. The suggested wholesale price is used here, because this is the only data that is available through 1979 for this study.

The price data used in this study has the slight advantage of conforming with the BLS data collection in these product categories. For a more complete discussion of the construction of price indexes as it relates to this project, see Appendix A.

The Products

Demand for all major product areas that are packaged in aerosol form and for which quantity data are available has been estimated. The list of products covered is in Table V-1, which includes the major aerosol products, whether or not CFCs were the propellant before regulation, and also whether or not products would have essential-use exemptions from the ban. Some pharmaceuticals are an example of the latter.

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*The Chemical Week study [18] from which d'Arge, et al. obtained their data is average prices paid. The price series is only available for the historical period (1960 to 1974) and not for the forecast period (1975 to 1979).

Table V-1

PRODUCTS STUDIED

- I. Personal Products
  - A. Antiperspirants/Deodorants
  - B. Hairsprays
  - C. Colognes
  - D. Shaving Creams
  - E. Residual
- II. Household Products
  - A. Household Wax
  - B. Household Laundry Products, including Spray Starch
  - C. Other Household Products
- III. Veterinary Products
- IV. Pharmaceutical Products
- V. Paints
- VI. Insecticides
- VII. Industrial Products
- VIII. Food
- IX. Automotive Products
- X. Total Demand

In the analysis, greater attention is given to personal products than to household products because, with the exception of shaving creams, personal products were almost completely propelled by CFCs prior to regulation.

Products that were not propelled by CFCs are, however, included in the range of products, because samples of consumer purchases between 1975 and 1979 show that almost all aerosol products, whatever the propellant, were somewhat affected by regulation. One sample of consumer purchases of aerosol products that is routinely conducted assembles data on the following aerosol products: air fresheners, bathroom cleaners (detergent type), three categories of A/D, disinfectants/deodorants (D/D), three types of insecticides, rug cleaners, shaving creams, spray starches, upholstery cleaners, whipped cream, and window cleaners.* Actual changes in consumer purchases of aerosols from 1975 to 1979, by product category, are tabulated.

In examining the data the most telling evidence of the decline in aerosol product demand independent of the propellant is in a comparison of 1976 and 1977 data. As seen in Table V-2, there was a 10 percent total decline in demand for aerosols between 1976 and 1977. Moreover, Table V-2 also shows that this decline in demand was not restricted to products with CFCs as a propellant. Aerosol products that were propelled by CFCs (hairsprays and A/D) dropped in sales 11 to 34 percent from 1976 to 1977. Even some aerosol products that were not propelled by CFCs prior to the announcement of the ozone depletion hypothesis dropped in sales from 1976 to 1977 by roughly the same percentages. Some examples are window cleaners (27.2%) and oven cleaners (21.2%).

The decline in demand in 1977 over 1976 is thus noteworthy for two reasons:

- 1977 was a year in which regulations were announced, namely, the labeling requirement and the proposed phase-out of CFCs. The announcement seems to have had a negative impact on many aerosols, not only those propelled by CFCs.

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*The data are in Aerosol Age [67].

Table V-2

CHANGE IN DEMAND FOR AEROSOLS

(By Product Category and Propellant, 1976 to 1977)

Product Category	Propellant Used* Pre-1974	Propellant Used* 1977	Percent Change in Demand** 1976 to 1977
Bathroom Cleaners (Detergent Type)	HC	HC	.2
Disinfectant/Deodorants (Room)	85% used CFC (15% HC)	70% CO_2 20% HC 10% CFC (but being reduced)	2.5
Other Air Fresheners			
Air Fresheners (Other than D/Ds)	95+% used HC (5% CFC)	HC	-9.4
Shaving Cream	HC	HC	.2
Hair Spray	A blend of 95+% CFC with HC	CFC/HC blends with HC % increasing rapidly	-11.7
Antiperspirants/Deodorants (3 Categories)	CFC	50-60% CFC 50-40% HC	-18. to -34.
Whipped Cream	N_2O and/or CO_2	N_2O and/or CO_2	2.4
Insecticides			0.0
House and Garden	HC	HC	
Flying Insect	HC	HC	
Residual	CO_2	CO_2	
Oven Cleaners	HC	HC	-21.2
Rug Cleaners	HC	HC	-3.7
Upholstery Cleaners	HC	HC	-1.0
Window Cleaners	HC	HC	-27.2
All Aerosols (Weighted Average)			-10.0

*Source: Industry estimates.

**Source: "SAMI Tracks Aerosol Sales," Aerosol Age [67].

- 1977 was a year of relative prosperity in the U.S. economy; that is, unlike 1975 to 1976, there was no recession and there was a relatively low rate of inflation. Thus, in the absence of regulatory impact, one would expect an increase in the demand for aerosols.

Comparison with Previous Studies. The number of products for which statistical estimates are made in this study is more complete than that of previous contractors studying CFCs. For example, d'Arge [24, p. 254] estimates seven aerosol categories.

- Hairsprays
- Pharmaceutical
- Insecticides
- Room deodorizers
- Perfumes, cosmetics, and toiletries
- Shaving products
- Antiperspirants/deodorants.

d'Arge double-counted hairsprays, shaving products, and A/D in his analysis since they are components of toiletries. It is also unclear why some products are included by d'Arge and others are not. The criterion was clearly not what products contained CFCs at the time of the ban; if this were true, insecticides and shaving creams would not be included. An explanation for his choice of products would be helpful.

The Data: Sources and Quality

It is important to be clear about the conceptual and measurement problems in the data used to estimate demand. A list of the variables in the data bank is included in Appendix B. Some of the problems with the data are included here.

The quantity data are for the number of units filled each year, 1960 to 1974, as reported to the Chemical Specialities Manufacturers Association (CSMA), a trade organization. By usual government standards, there are greater measurement errors in the CSMA data [17] than in national income and product (NIPA) data. This is well-known by users of the data.* The measurement errors exist largely because data on individual products are based only on fillers and marketers that report their annual units filled to CSMA. The coverage is incomplete within each year, and coverage varies from year-to-year.** CSMA's estimate of the total number of aerosol units filled, on the other hand, is based on container information collected not only by CSMA but also by the U.S. Bureau of the Census and by the Container Manufacturers Institute (CMI).

There is, however, no alternative source of information on quantities filled or used by consumers, that is if one requires (at least) annual data. The U.S. Bureau of the Census collects data on the relevant commodities only in Census years.***

The sources of the price data vary. Some of it is collected by BLS. Others have been assembled and indexed by the contractor. A discussion of price data is in Appendix A.

The Federal government routinely collects information on real disposable personal income and population. Population is estimated by the U.S. Bureau of the Census and real disposable income by the Bureau of Economic Analysis (BEA). This is "hard" data relative to, say, the quantity data, because the measurement errors are small, and the conceptual and statistical bases for collecting this data are consistent over time.

The Criteria for Accepting Statistical Results

The standard objectives in any such statistical work are to obtain estimates of the historical relationships (1960 to 1974 in this case) in which both the overall measure of "goodness of fit" (R^2) is satisfactory, and the coefficients (here, each price term and the income variable) have the right signs and are statistically significant.

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*Chemical Week [18], d'Arge [24], Bailey [8], and IR&T [36].

**For a careful discussion of this problem of coverage, see Johnsen and Dorland [39].

***Census assembles value of shipments data on various product areas considered in this study every five years (1967, 1972, and 1977). For these years, household products (SIC 2842), cosmetics (SIC 2844), paints (SIC 2851), and veterinary and "human" pharmaceutical (SIC 2834), among others, are available. Unlike metal aerosol containers (SIC 3411), there is no annual "Current Industrial Report" (except for pharmaceuticals) for the relevant products.

The results of the estimation in this study are in Appendix B. In general, the estimates are reasonable, but there are two very important qualifications, both related to price variables. One, it was impossible to construct price indexes in many commodity groups, so often the per capita demand for an aerosol was estimated only as a function of real income per capita. And two, the price term had the wrong sign in the hairspray equation.*

Where compromises are made, the general criterion for selecting an equation is its ability to "explain" the per capita demand for aerosols before regulation, 1960 to 1974, by means of the income variable. This is appropriate since the major objective is statistically to exclude the recession of 1974 to 1975 and 1980 from demand with regulation. Thus, the coefficient on income clearly had to have the right sign (> 0) and be statistically significant. One also wishes for a reasonably sized income elasticity. What is reasonable, however, is somewhat complex. The subject is readdressed later, where the estimated values of the coefficients, 1960 to 1974, are used to predict demand between 1975 and 1979 and the results are reviewed on the basis of outside information from a Neilsen survey.

Comparison with Previous Studies. The criterion that income elasticity must have the right sign differs from that of d'Arge in his study of CFC use in aerosol products. His criterion was that the "own price" term had to have the right sign [24, p. 63]. The reason for this difference is that the objectives of his econometric work were different. d'Arge was seeking to evaluate consumers' surplus, whereas the objective of this study is to abstract the impact of recessions (specifically, changes in real disposable per capita income) from the historical record.

It was inappropriate for IR&T [36] to use the equations estimated by d'Arge, because IR&T's objective is identical to that of this study, namely, to estimate demand in the absence of recession and regulation.

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*The simple correlation between the dependent variable (quantity of aerosol hairsprays per capita) and the real price of aerosol hairsprays also had the wrong sign.

Aerosol Demand, 1960 to 1974

The equations used to predict demand in the absence of regulation, by product, are given in a standard format in Appendix B. A summary of elasticities by equation is shown in Table V-3. Two results are:

- One can largely explain what happened to the per capita demand for any aerosol product on the basis of its real "own" price, when price data are available; its real substitute price, again insofar as data are available; and real disposable per capita income.
- Coefficients generally have the correct sign and are statistically significant for the specification of the equations.

These estimates are, however, necessarily crude because of the length of historical series (15 years, annual data) and also because of the quality of the data on quantity used. One should therefore use the results with caution.

Predictions of Demand, 1975 to 1979

The primary objective, as noted earlier, is to provide a basis on which to estimate what the demand for aerosols would have been in the absence of regulation. Having selected equations that provide reasonable explanations of the historical period, 1960 to 1974, they are used to predict demand in the forecast period, 1975 to 1979. The approach taken involves three steps:

- Test for the homogeneity of the equations over the forecast period. First, the equations that were selected to explain the historical period, 1960 to 1974, are reestimated for the forecast period, 1975 to 1979. Then the appropriate test of homogeneity is applied, namely, the Chow test, to see if these equations predict the same results for 1975 to 1979. The results, by equation, are in Appendix B. In general, it is found that

Table V-3

ELASTICITIES IN THE AEROSOL DEMAND EQUATIONS

(1960 to 1974)

Equation Number	Product Category	Real Own Price Elasticity	Real Substitute Price Elasticity	Real Income Elasticity	Other Independent Variables
I.	Personal Products (QAPP)	-0.7743	1.7136	3.6639	
I.A	Antiperspirants/Deodorants (QADA)[a]	-1.2318	1.2909	4.9736	
I.B	Hairsprays (QAH)[a]	b		4.2181	-0.2108[c]
I.C	Colognes (QAC)[a]	-1.7100	2.2022	4.2268	
I.D	Shaving Creams (QASC)[a]	b	b	1.0509	
I.E	Residual Personal Products (QAPPR)[a]			2.5879	
II.	Household Products (QAHH)[a]	b	b	2.3701	
II.A	Household Wax	b		2.9773	
II.B	Household Starch and Laundry Products (QAHS)	b		3.1878	
II.C	Residual Household Products (QAHHR)	not estimated			
III.	Veterinary Products (QAV)[a]			2.2341	
IV.	Pharmaceutical Products (QAPH)[a]	-0.1887	1.3749	1.9174	
V.	Paints (QAP)[a]			2.6435	
VI.	Insecticides (QAI)[a]	-0.2848	0.0448	0.8837	
VII.	Industrial Products (QAIN)[a]				4.2517[d]
VIII.	Food (QAF)[a]			0.6243	
IX.	Automotive Products (QAA)[a]			3.0214	
X.	Total Demand (QAT)[e]				

[a] This equation is used in an identity to estimate total aerosol demand (QAT) in the absence of regulation.

[b] A price index was constructed for the numerator in the price term, but (a) the correlation between the dependent variable and the price term did not have the right sign, and (b) it also did not have the right sign in specifications of the equations that were estimated.

[c] Dummy for change in hairstyles.

[d] Index of industrial production.

[e] Total demand (QAT) for all aerosols is obtained by summation of the results of its components, for reasons given in the text. Specifically, QAT = (QADA + QAH + QAC + QASC + QAPPR + QAHH + QAV + QAPH + QAP + QAI + QAIN + QAF + QAA). Thus, there are no direct statistical estimates of either price or income elasticities of the demand for the aggregate: all aerosol products (QAT). A weighted average of the income elasticity of QAT, which can be calculated using the estimates of its components, is 2.6.

Source: Equations in Appendix B.

equations that explain the past (1960 to 1974) do not explain the behavior of output from 1975 to 1979; in addition, the difference in the results are more likely to be statistically significant among the products which were previously propelled by CFCs.

- Obtain the predicted values of demand, by product, for the forecast period, 1975 to 1979. This involves taking actual observations of the independent variables (income and price), 1975 to 1979, using estimated values of the coefficients on income and price, and solving this equation for predicted demand (Q - HAT) in the absence of regulation. Predicted demand is then compared with actual demand. The difference between actual and predicted demand by product is in Appendix B, and this difference becomes the area for close examination.
- Replace demand predicted by an equation in cases in which the results are implausible with estimates of demand in the absence of regulation based on more plausible hypotheses and outside information.

The Plausibility of Predicted Demand

A comparison of the actual and predicted values of each equation indicates that there is generally a good corresondence between a priori hypotheses and the statistical results about differential economic impact among products. For most products that were propelled by CFCs prior to regulation, there is a substantial difference between actual quantities filled and estimates based on history. For those propelled by alternative propellants, the differences between actual and predicted demand are generally smaller.

This section examines the plausibility of the statistically predicted demand for 1975 through 1979 and adjusts the predictions in five cases: hairsprays, A/D, food, automotive products, and paints.

The Hairspray Estimates.

The hairspray estimates have been studied with some care because of the sheer size of the market and because there is information on total consumer purchases of hairsprays, as well as the share of purchases by dispensing method (aerosol and nonaerosol). The question is: Do the statistical predictions make sense in view of this other information?

The procedure for answering this question -- and the assumptions made -- affect the results. Therefore, the six steps involved are outlined and the calculations are shown in Table V-4.

a. Begin with information on the actual percentage use of hairsprays, aerosol versus nonaerosol, both prior to the announcement of the ozone depletion hypothesis (June 1974) and year-by-year since then. The possible sources of control data are Nielsen surveys and Towne-Oller data, both of which have historical information on purchases of hairsprays by dispensing form. The Nielsen survey of unit volume sales is used.

b. Take the actual quantity data for aerosol use, 1975 to 1979, and calculate the nonaerosol portion and the total demand for hairsprays, assuming that one unit of an aerosol hairspray equals one unit of a nonaerosol hairspray.

c. Adjust this total on the assumption that each unit of nonaerosol hairsprays lasts twice as long as an aerosol (that is, that the resin content in a nonaerosol is double that in an aerosol, on a per unit basis).* Therefore multiply the nonaerosol units by 2 to get an aerosol equivalent.

d. Calculate per capita consumption in aerosol equivalents.

e. Make an assumption about the extent to which an aerosol hairspray would have increased its share of the market in the absence of regulation. Industry estimates that aerosol hairsprays would have encompassed virtually all of the market had aerosol use of CFCs not been banned. Thus, to estimate total aerosol demand in the absence of regulation, it is assumed that aerosol hairsprays

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*Sources: Industry and the fact that the Federal Trade Commission has not halted advertisements that suggest two or three aerosols equal one nonaerosol. The advantage of the longer "life" of nonaerosols is said to be at least offset by the greater convenience of aerosols.

Table V-4

ESTIMATED DEMAND FOR HAIRSPRAYS WITHOUT REGULATION, 1975 TO 1979

	Year					
	1974	1975	1976	1977	1978	1979
Step a. Use of Hairsprays (Percent)						
Aerosol	93.2	85.7	76.4	69.0	64.8	63.1
Nonaerosol	6.8	14.3	23.6	31.0	35.2	36.9
Total	100.0	100.0	100.0	100.0	100.0	100.0
Step b. Quantities Filled (Millions of Units)						
Aerosol	376	308	285	223	224	238
Nonaerosol	27	52	88	100	122	139
Total Units Filled	403	360	373	323	346	377
Step c. Aerosol Equivalent of Nonaerosols (Millions of Units)						
Aerosol	376	308	285	223	224	238
Nonaerosol*	55	103	176	200	243	278
Total Aerosol Equivalent	431	411	461	423	467	516
Step d. Per Capita Consumption						
Total Aerosol Equivalent (Millions)	431	411	461	423	467	516
Population (Millions)	212	214	215	217	219	221
Per Capita Consumption (Units)	2.03	1.92	2.14	1.95	2.13	2.34
Step e. Projected Aerosol Demand (Millions of Units)						
Total Aerosol Equivalent		411	461	423	467	516
Aerosol Demand Without Regulation		390	438	402	444	490

*See text for explanation of calculation and assumptions.

Sources: Nielsen, CSMA, and transformations.

would have been 95 percent of total aerosol equivalents each year, 1975 to 1979.

This procedure results in an estimate of what the actual demand for aerosol hairsprays would have been from 1975 to 1979 in the absence of regulation. These results can be compared with the estimates based on statistical work. A summary is in Table V-5.

Table V-5

COMPARISON OF ESTIMATES OF DEMAND FOR AEROSOL HAIRSPRAYS WITHOUT REGULATION

(Millions of Units)

	Year					
	1975	1976	1977	1978	1979	Total
1. Statistical Estimates	386	440	511	604	644	2,585
2. Nonstatistical Estimates (Steps a Through e)	390	438	402	444	490	2,164
Difference	-4	-2	109	160	154	421

A graph of actual demand and of demand in the absence of regulation, as predicted statistically and with adjusted Nielsen data, is illustrated in Graph V-1.

The results of the analysis in steps a through e are used instead of the results of the econometric work in summing demand for aerosol hairsprays in the absence of regulation. A result is reduced impact relative to that predicted by the statistical equation.

The Antiperspirants/Deodorants Equation. As in the case of hairsprays, the actual and predicted demand for A/D are checked against outside information. This is an important product category because of the large value of shipments involved. The analysis is possible because the Nielsen data is also available for A/D.

The steps in evaluating the results are the same as for hairsprays. The results are reported in Table V-6.

a. The Nielsen Survey on unit volume of sales is used.
b. The same assumption is used to estimate total quantities filled, namely one unit of aerosol equals one unit of nonaerosol.

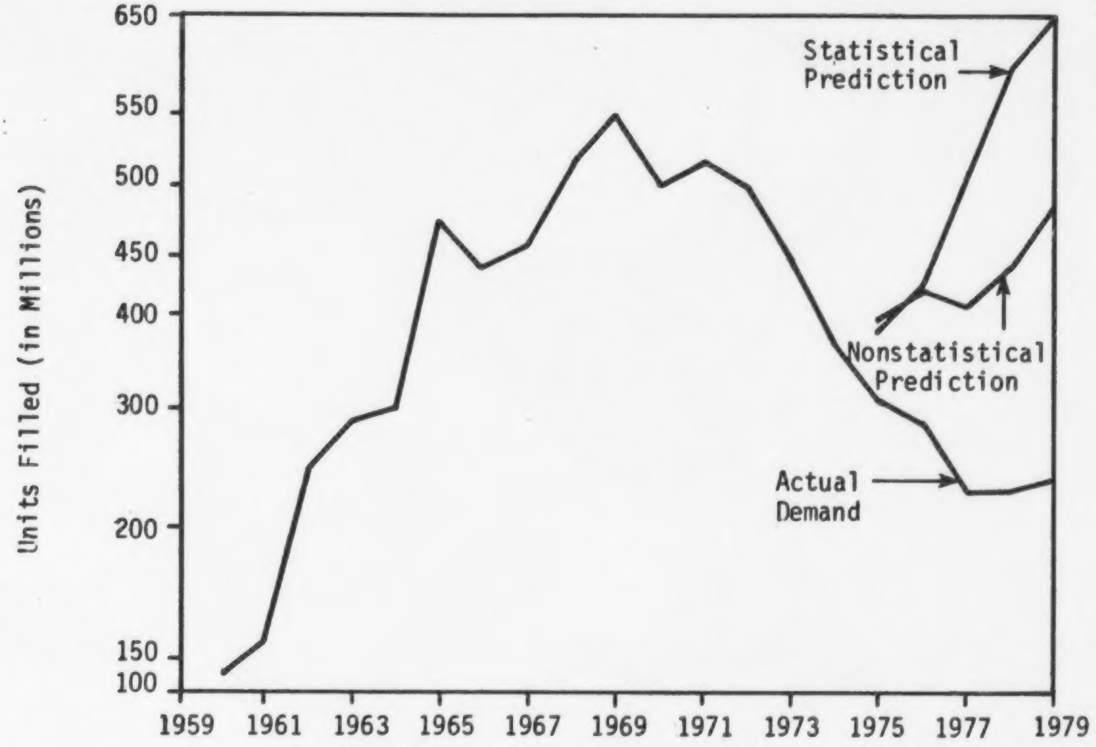
Table V-6

ESTIMATED DEMAND FOR ANTIPERSPIRANTS/DEODORANTS, WITHOUT REGULATION, 1975 TO 1979

	Year					
	1974	1975	1976	1977	1978	1979
Step a. Use of Hairsprays (Percent)						
Aerosol	76.2	71.6	58.3	46.2	42.6	39.8
Nonaerosol	23.8	28.4	41.7	53.8	57.4	60.2
Total	100.0	100.0	100.0	100.0	100.0	100.0
Step b. Quantities Filled (Millions of Units)						
Aerosol	588	532	403	310	235	268
Nonaerosol	184	211	288	361	317	405
Total Units Filled	772	743	691	671	552	673
Step c. Aerosol Equivalent of Nonaerosols (Millions of Units)						
Aerosol	588	532	403	310	235	268
Nonaerosol*	367	422	576	722	633	810
Total Aerosol Equivalent	955	954	979	1,032	868	1,078
Step d. Per Capita Consumption						
Total Aerosol Equivalent (Millions)	955	954	979	1,032	868	1,078
Population (Millions)	212	214	215	217	219	221
Per Capita Consumption (Units)	4.50	4.46	4.55	4.76	3.96	4.88
Step e. Projected Aerosol Demand (Millions of Units)						
Total Aerosol Equivalent		954	979	1,032	868	1,078
Total Aerosol Demand Without Regulation		744	783	826	694	862

*See text for explanation of calculation and assumptions.

Sources: Nielsen, CSMA, and transformations.



Graph V-1. Adjusted Results for Hairsprays.

c. To get the total aerosol equivalent, take the same assumption -- that a nonaerosol A/D lasts twice as long as an aerosol one.*

d. The per capita consumption calculation is the same.

e. Industry estimates that aerosol A/D would have encompassed most of the market had aerosol use of CFCs not been banned. Thus, to estimate total aerosol demand in the absence of regulation, it is assumed that aerosol A/D would be 78 percent of total aerosol equivalents in 1975 and 80 percent thereafter.

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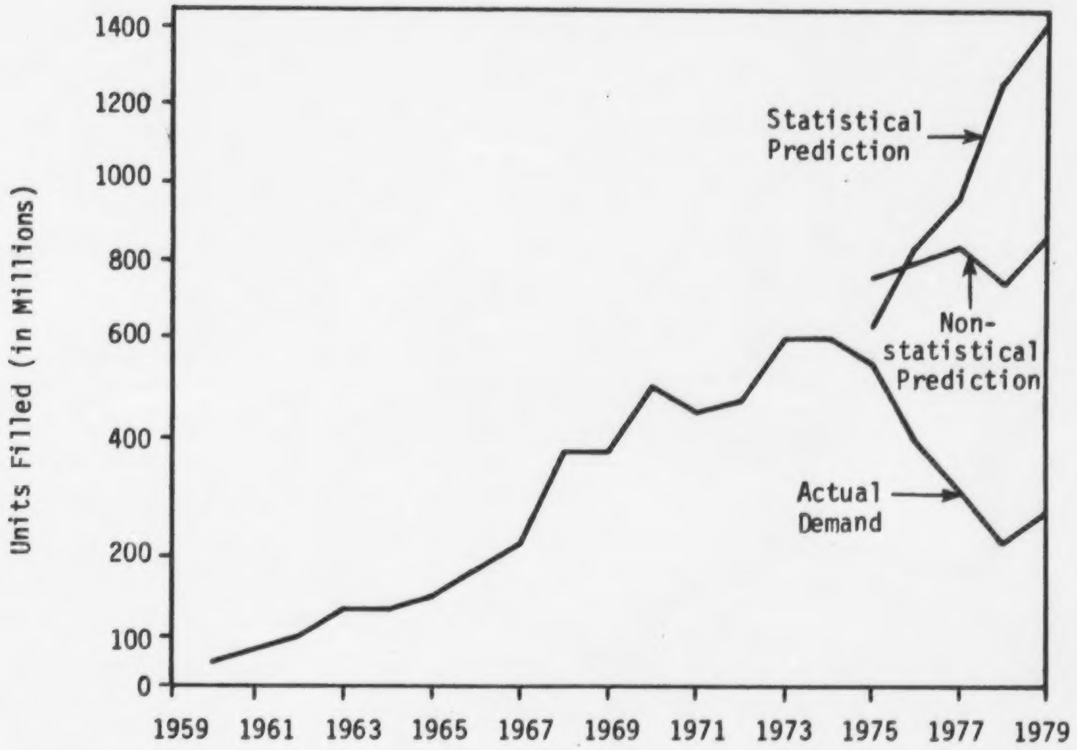
*Source: Industry estimates.



Graph V-2. Adjusted Results for Antiperspirants/Deodorants.

These estimates of total demand for A/D without regulation can be compared with the results of the statistical work. A summary of the numbers is shown in Table V-7, and the results using this outside information are added to the graph of the difference between actual and predicted demand for A/D. Graph V-2 shows the difference these results make. The results of the analysis in steps a through e are used instead of the results of the econometric work in summing demand for aerosol A/D in the absence of regulation. A result of this adjustment is to lower impact relative to that predicted by the statistical equation.

Table V-7

COMPARISON OF ESTIMATES OF THE DEMAND FOR AEROSOL ANTIPERSPIRANTS/DEODORANTS WITHOUT REGULATION

(Millions of Units)

	Year					
	1975	1976	1977	1978	1979	Total
1. Statistical Estimates	643	818	975	1,272	1,413	5,121
2. Outside Information (Steps a Through e)	744	783	826	694	862	3,909
Difference	-101	35	149	578	551	1,212

The Food Equation. There are difficulties with the quantity data that are used in the food equation. Specifically, the largest manufacturer of spray cooking lubricants did not report its units filled until 1974, long after it had become a major product. As a result, the statistical results for the food equation cannot be used. Therefore, the actual figures for 1975 to 1979 are defined as demand in the absence of regulation. This is equivalent to saying regulation had no impact on spray cooking lubricants, which is untrue; however, there are no data available to correct this problem.

The Automotive Products Equation. Actual demand for aerosol automotive products between 1975 and 1979 exceeded demand predicted by the equation, and the introduction of plausible energy-related variables does not improve these results. The statistical results are therefore discarded, and predicted demand is assumed to equal actual demand. This is equivalent to saying regulation had no impact on aerosol auto product sales.

The Paint Equation. On the basis of scattered, nonquantitative information, the estimates of the demand for aerosol paints in 1978 and 1979 in the absence of regulation do not make sense. Therefore, the predicted value of 367 million units for 1977, has been accepted but also used for 1978 and 1979, thus reducing hypothesized demand for aerosol paints in the absence of regulation for these two years.

The Total Demand for Aerosol Products Without Regulation, 1975 to 1979

The total demand for aerosols in the absence of regulation can now be calculated. Total demand is obtained by summing the 1975 to 1979 predictions of demand in the absence of regulation for each product category. The results are shown in Table V-8.

Two types of information are used to calculate the total demand for aerosols. For all equations except five, demand is that predicted by the statistical equations. In three of the remaining cases (food, paint, and automotive products), actual values rather than predicted values are generally used, for reasons explained earlier in this chapter. In the case of hairsprays and A/D, the estimates are based on actual consumer purchases between 1975 and 1979. The nature of these adjustments is explained earlier in the chapter.

For all other product categories, the statistical estimates are unadjusted for two reasons. One is that relatively hard data, such as Nielsen's surveys of aerosol and nonaerosol sales of hairsprays and A/D, is not available for other product categories. In addition, however, the scattered, nonquantitative market information available suggests adjustments need not be made, unlike the case, say, of the paint equation.

The Demand for Aerosols With Regulation, 1975 to 1990

The demand for aerosols with regulation, 1975 to 1979, is summarized, by product, in Table V-9. This consists of actual units filled of aerosols, as tabulated by CSMA.

The Quantity Wedge: The Difference Between Demand for Aerosols With and Without Regulation, 1975 to 1979

The "quantity wedge" is the total quantity of aerosol products that were not produced between 1975 and 1979 as a result of regulation. It is the difference between the total number of aerosols that would have been filled had there been no regulation and the actual number filled. The differences are shown in Table V-10 (obtained by subtraction of data in Table V-9 from that in Table V-8).

Table V-8

ESTIMATED DEMAND FOR AEROSOLS WITHOUT REGULATION, 1975 TO 1979

(Millions of Units)

Product Category	1975	1976	1977	1978	1979
I. Personal Products (QAPP)					
A. Antiperspirants/Deodorants (QADA)	744	783	826	694	862
B. Hairsprays (QAHS)	390	438	402	444	490
C. Colognes (QAC)	184	211	250	314	415
D. Shaving Creams (QASC)	158	164	171	180	184
E. Residual (QAPPR)	156	170	186	207	216
II. Household Products (QAHH)	802	866	944	1,041	1,084
III. Veterinary Products (QAV)	16	17	18	20	21
IV. Pharmaceutical Products (QAPH)	68	68	75	81	84
V. Paints (QAP)	307	334	367	367	367
VI. Insecticides (QAI)	135	133	140	142	149
VII. Industrial Products (QAIN)	60	94	118	152	181
VIII. Food (QAF)	150	151	125	143	141
IX. Automotive Products (QAA)	78	90	120	151	166
Total Demand (QAT)	3,248	3,519	3,742	3,936	4,360

Sources: Equations in Appendix B and industry.

Table V-9

ACTUAL DEMAND FOR AEROSOLS WITH REGULATION, 1975 TO 1979

(Millions of Units)

Product Category	1975	1976	1977	1978	1979
I. Personal Products (QAPP)					
A. Antiperspirants/Deodorants (QADA)	532	403	310	235	268
B. Hairsprays (QAHS)	308	285	223	224	238
C. Colognes (QAC)	80	63	11	24	32
D. Shaving Creams (QASC)	99	173	111	161	134
E. Residual (QAPPR)[a]	13	23	13	37	37
II. Household Products (QAHH)	567	532	600	628	653
III. Veterinary Products (QAV)	14	16	18	15	18
IV. Pharmaceutical Products (QAPH)	43	34	52	47	63
V. Paints (QAP)	278	306	331	309	302
VI. Insecticides (QAI)	102	114	120	132	199
VII. Industrial Products (QAIN)	75	94	110	124	134
VIII. Food (QAF)	150	151	125	143	141
IX. Automotive Products (QAA)	78	90	120	151	166
X. Statistical Discrepancy[b]	16	11	6	2	13
Total Demand (QAT)	2,355	2,295	2,150	2,232	2,398

[a] QAPPR = QAPP - (QAPH + QASC + QAC + QAHS + QADA).

[b] Statistical discrepancy includes miscellaneous categories and rounding errors.

Sources: CSMA [17] and transformations.

Table V-10

THE DIFFERENCE BETWEEN ESTIMATED AND ACTUAL DEMAND FOR AEROSOLS, 1975 TO 1979

(Millions of Units)

Product Category	1975	1976	1977	1978	1979
I. Personal Products (QAPP)					
A. Antiperspirants/Deodorants (QADA)	212	380	516	459	594
B. Hairsprays (QAHS)	82	153	179	220	252
C. Colognes (QAC)	104	148	239	290	383
D. Shaving Creams (QASC)	59	-9	60	19	50
E. Residual (QAPPR)[a]	143	147	173	170	179
II. Household Products (QAHH)	235	334	344	413	431
III. Veterinary Products (QAV)	2	1	0	5	3
IV. Pharmaceutical Products (QAPH)	25	34	23	34	21
V. Paints (QAP)	29	28	36	58	65
VI. Insecticides (QAI)	33	19	20	10	-50
VII. Industrial Products (QAIN)	-15	0	8	28	47
VIII. Food (QAF)	0	0	0	0	0
IX. Automotive Products (QAA)	0	0	0	0	0
X. Statistical Discrepancy[b]	-16	-11	-6	-2	-13
Total Demand (QAT)	893	1,224	1,592	1,704	1,962

[a] QAPPR = QAPP - (QAPH + QASC + QAC + QAHS + QADA).

[b] Statistical discrepancy includes miscellaneous categories and rounding errors.

Sources: Tables V-8 and V-9.

THE AEROSOL SECTOR, 1980 TO 1990

In addition to assessing lost quantities for the historical period 1975 to 1979, one must also make reasonable estimates of quantity losses for the aerosol sector (fillers, aerosol containers, and valves) for 1980 through 1990, the termination of the period of analysis (see Chapter II, especially for the assumption about the dedication of capital equipment and its remaining economic life).

The estimates made in this study are based on the assumption held by knowledgeable members of the aerosol industry that without regulation the industry would essentially have been a mature industry by 1980. This simply means that the rate of growth in demand per capita for aerosol products, on average, would have grown at a substantially lower rate than in the past.

More specifically, aerosol members speak of the total market for aerosols as having become 90 percent "saturated" and 10 percent "growth" in the absence of regulation. In the case of the saturated portion of the market, it would have grown at the same rate of growth as the population in the U.S., say about .8 percent a year.* Various estimates are given for the unsaturated portion. Some members of industry assume growth rates of about 10 percent per year for the unsaturated portion; others tie the growth rate to projections of real disposable personal income per capita.

Estimates of Demand Without Regulation, 1980 to 1990

The total number of units filled without regulation is forecast on the basis of a crude approximation of the "mature industry" hypothesis. Specifically, it is assumed that total demand for aerosols in the absence of regulation would have grown by one percent a year each year between 1980 and 1990. This one percent growth rate, while far lower than the preregulation growth rates in the industry, is slightly more than the forecasted increase in population of .8 percent a year, which is the best industry estimate of growth in the saturated portion of the market. A lower growth rate of .5 percent a year was used between 1979 and 1980 as a crude adjustment for two countervailing influences. One of these was the transition period from aerosols being unsaturated to being saturated markets; this would result in a growth rate higher than one percent for 1979 to 1980. The other was the recession of 1979 to 1980, which would have resulted in an actual decrease in demand between 1979 and 1980, other things being equal.

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*A more plausible set of marketing information would relate the demand for a particular (saturated) product with the growth rate of the relevant age distribution of the population. For an example of this, see the Chemical Week study of the economic impact of (then potential) regulation of CFCs as aerosol propellants [18].

Estimates of Demand With Regulation, 1980 to 1985

Demand with regulation must also be forecast. Container data for eight months in 1980 were used to forecast actual demand for 1980 as 2,146 million units filled. Industry is assumed to grow at a higher rate between 1981 and 1985 with regulation than without regulation; 2 percent a year is used. This higher growth rate with regulation is based on hypotheses about the extent to which certain product areas, such as aerosol colognes, had been successfully reformulated only by 1980 and will thus grow at a more rapid pace in the near future. The results are shown in Table V-11.

Table V-11

DEMAND WITH AND WITHOUT REGULATION, 1980 TO 1985

(Millions of Units)

Year	Without Regulation	With Regulation
1980	4383.8	2146.0
1981	4427.6	2188.9
1982	4571.9	2232.7
1983	4516.6	2277.4
1984	4561.8	2322.9
1985	4607.4	2369.4

Estimates of Demand, 1986 to 1990

As noted in Chapter II, the aerosol industry believes that beginning in 1985 consumer tastes with respect to aerosols will change and by 1990 will have returned to preregulation levels. This means that the difference between demand for aerosols in the absence of regulation will converge on demand for aerosols with regulation by 1990. Estimates of the difference are shown in Table V-12.

Table V-12

DIFFERENCE BETWEEN DEMAND WITH AND WITHOUT REGULATION, 1986 TO 1990

Year	Millions of Units Filled
1986	2,000
1987	1,500
1988	1,000
1989	500
1990	0

Summary of Aerosol Quantity Losses, 1975 to 1990

The difference between quantity estimates of the demand for aerosols with and without regulation from 1975 to 1990 is summarized in Table V-13. The quantity losses due to regulation are summarized in Graph V-3. These quantity losses of 25.8 billion units between 1975 and 1990 are for each of three aerosol sectors: filling, containers, and valves.

THE CHEMICAL SECTOR, 1975 TO 1990

The economic impact on chemical producers is an estimate of losses to CFC manufacturers and to the manufacturers of some of the chemicals that are their precursors. The approach to estimating quantity losses in the chemical sector is to use the results from the aerosol sector and supplement them with outside information. The supplemental information is an estimate of the extent to which alternative propellents -- HCs and compressed gases -- would have made inroads into CFC markets even without regulation. After demand for CFCs with and without regulation is estimated, the derived demands for chemicals that are precursors to CFCs are estimated using proportional relationships.

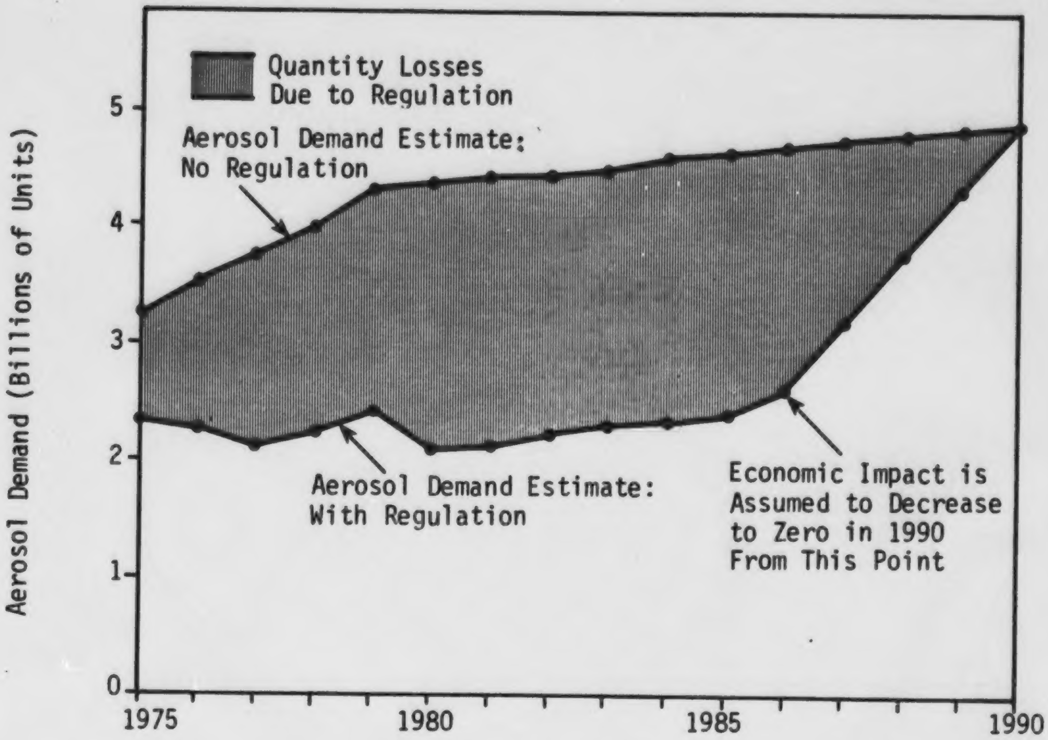
Table V-13

TOTAL QUANTITY LOSSES IN AEROSOLS WITH AND WITHOUT REGULATION, 1975 TO 1990

(Millions of Units)

Year	Demand Without Regulation	Demand With Regulation	Difference
1975	3,248	2,355	893
1976	3,519	2,295	1,224
1977	3,742	2,150	1,592
1978	3,936	2,232	1,704
1979	4,360	2,398	1,962
1980	4,384	2,146	2,238
1981	4,428	2,189	2,239
1982	4,472	2,233	2,239
1983	4,517	2,277	2,240
1984	4,562	2,323	2,239
1985	4,607	2,369	2,238
1986	4,653	2,653	2,000*
1987	4,699	3,199	1,500*
1988	4,746	3,746	1,000*
1989	4,793	4,293	500*
1990	4,841	4,841	0*
Total 1975-1990	69,507	43,699	25,808
Total 1976-1990	66,259	41,344	24,915

*Linear reduction to zero from 1986 to 1990.



Graph V-3. Aerosol Quantity Losses.
Source: JACA estimates.

Demand for CFCs With Regulation

Estimates of the actual output of CFCs for aerosol use with regulation are summarized in Table V-14 for 1975 to 1990. There are two notes:

- The source of the data on the use of CFCs as aerosol propellants is CFC producers. One must use industry estimates because the Federal agency that collects data on CFC production -- the U.S. International Trade Commission -- does not break out quantity data by end-use.
- The use of CFCs as propellants that are currently exempt from regulation is assumed to remain at the 1979 level of 21 million pounds for each year until 1990.

Table V-14

OUTPUT OF CFCS FOR AEROSOL PROPELLANTS, WITH REGULATION, 1975 TO 1990

(Millions of Pounds)

Year	Total Quantity (CFC-11, CFC-12, and CFC-114)
1975	443
1976	420
1977	242
1978	165
1979	21
1980	21
1981	21
1982	21
1983	21
1984	21
1985	21
1986	21
1987	21
1988	21
1989	21
1990	21

Source: Industry.

Demand for CFCs Without Regulation

An evaluation of any change in the demand for CFCs and their precursor chemicals must take into account the fact that alternative propellants -- chiefly HCs but also compressed gases -- would have made some inroads into the CFC propellant market in the absence of regulation.

To evaluate further inroads, one needs some knowledge of CFC use prior to the announcement of the ozone depletion hypothesis. Among the key pieces of information are the following:

- About half of aerosol products in the U.S. in 1973 used CFCs as propellants; the rest did not.
- The primary alternative to CFCs were HCs, which were less expensive than CFCs but more flammable.
- Generally, the products that used CFCs in 1973 were products in which CFCs' fire retardant property or their inertness were viewed as critical.
- There was some "blending" even in alcohol-based products due to the lower price of HCs relative to CFCs. "Blending" refers to the fact that one type of propellant is mixed with other types.

Through discussions with industry, an estimate was made of the inroads HCs would have made without regulation, on a product-by-product basis. The issue was discussed with three groups: CFC manufacturers, HC producers, and marketers of products that used CFCs prior to regulation. In general, the results are:

- CFC manufacturers perceived that the market share for CFCs in aerosols would have declined 4 to 5 percent a year in the absence of regulation, but still increase in absolute terms.
- HC manufacturers estimated that the inroads they would have made in the absence of regulation were about 3 percent a year, but that 3 percent was contingent on (a) increased use in hairsprays, and (b) further blending in general.

- Marketers estimated a zero to 2 percent inroad, again, subject to a critical assumption about the hairspray market. The results of discussions with marketers of many products, by product area, are summarized in Table V-15.

In the early Seventies, one company, Nestle-Le Mur, marketed a hairspray that was propelled by HCs rather than CFCs. Since hairsprays are a major product when measured in terms of value of shipments, the response of other marketers of hairsprays to this decision by Nestle-Le Mur was assessed.

The response received from marketers was clear. No other marketer of a major hairspray reported that its own company had decided that the savings in propellant costs outweighed the possible dangers of a more flammable product. Interestingly, some were concerned that their competitors might decide otherwise. Thus, the discussions with marketers of hairsprays leaves the issue of the increased use of HCs undecided.

A 3 percent decline in the use of CFCs is used on the assumptions that further blending of HCs with CFCs would have occurred in unspecified product areas, and that some producers of hairsprays would have switched from CFCs to HCs, even though each firm indicated that it did not plan to do so.

Table V-16 summarizes the demand for CFCs as aerosol propellants in the absence of regulation. This is estimated on the basis of:

- The estimated demand for aerosols in the absence of regulation, 1975 to 1990
- The estimate of a 3 percent decline in the use of CFCs as propellants, 1975 to 1990, in the absence of regulation
- The average pounds of CFCs per aerosol unit filled.

The Quantity "Wedge" for CFC Demand, 1975 to 1990

It is estimated for the time period from 1975 to 1990 that 8.8 billion pounds of CFCs will not be produced that would have been produced had there been no regulation. The numbers, year-by-year, are shown in Table V-17. This quantity wedge is shown in Graph V-4. The size of the quantity wedge generated by JACA (10,295 million pounds) is close to independent estimates made by DuPont (10,454 pounds).

Table V-15

THE SWITCH TO ALTERNATIVE PROPELLANTS

Product	Switch/No Switch
Antiperspirants*	No Switch from CFCs
Antistatic Products	No Switch from CFCs
Colognes	No Switch from CFCs
Deodorants*	? on Switching
Spray Cooking Lubricants	No Switch from CFCs
Hairsprays	?
Household Products	? on Further Switching
Industrial Products	No Further Switch from CFCS
Veterinary Products	No Further Switch from CFCs

*Antiperspirants are about 80 percent of the A/D category. The reformulation problems are entirely different, and everyone agrees that no one would have switched from CFCs to HCs in the antiperspirant market in the absence of regulation.

Source: Industry.

Table V-16

DEMAND FOR CFCS AS AEROSOL PROPELLANTS WITHOUT REGULATION, 1975 TO 1985

Year	Aerosol Demand in the Absence of Regulation[a] (Millions of Units)	CFC Use Per Unit Filled[b] (Pounds/Unit)	Estimated CFC Use in the Absence of Regulation (Millions of Pounds)
1975	3,248	.188	611
1976	3,519	.183	644
1977	3,742	.178	666
1978	3,936	.172	677
1979	4,360	.167	728
1980	4,384	.162	710
1981	4,428	.157	696
1982	4,472	.152	680
1983	4,517	.148	669
1984	4,562	.143	652
1985	4,607	.139	640
1986			621[c]
1987			602[c]
1988			584[c]
1989			566[c]
1990			549[c]

[a] Based on this study's projections of aerosol demand in the absence of regulation (Table V-13).

[b] Based on actual data from CSMA on units filled and CFC output for 1975 and 1976. From 1976 on, demand for CFCs per unit filled declines at 3 percent a year in the absence of regulation.

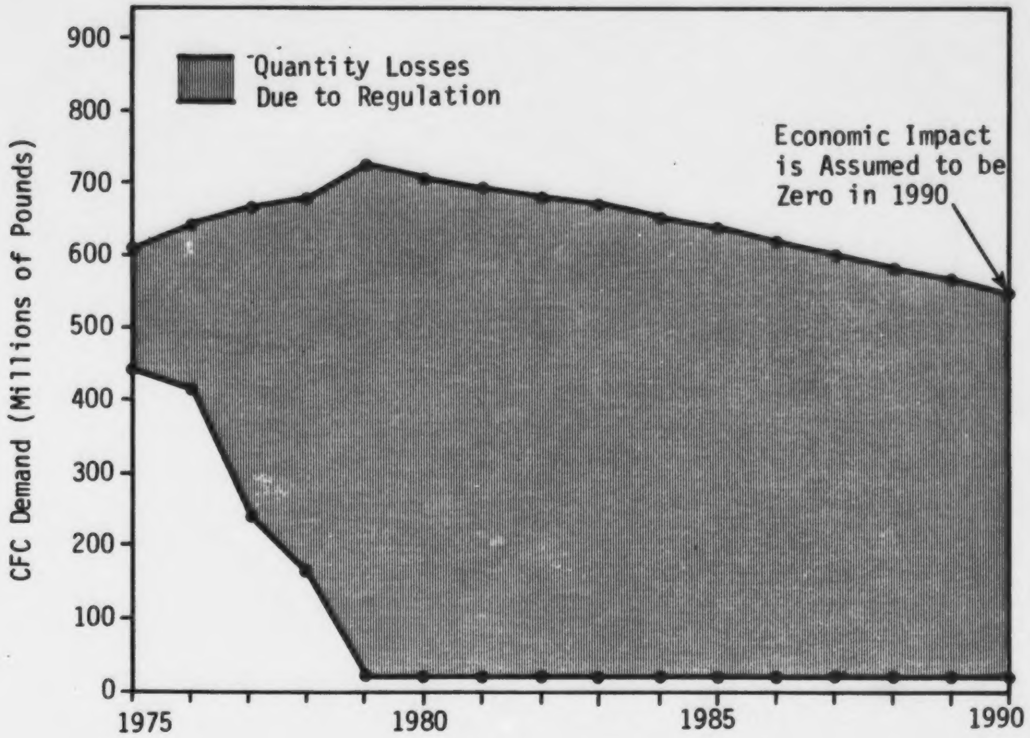
[c] Use reduced 3 percent a year from previous year.

Table V-17

THE CFC WEDGE

(Millions of Pounds)

Year	CFC Output Without Regulation	CFC Output With Regulation	The Difference or Wedge
1975	611	443	168
1976	644	420	224
1977	666	242	424
1978	677	165	512
1979	728	21	707
1980	710	21	689
1981	696	21	675
1982	680	21	659
1983	669	21	648
1984	652	21	631
1985	640	21	619
1986	621	21	600
1987	602	21	581
1988	584	21	563
1989	566	21	545
1990	549	21	528
Total 1975-1990	10,295	1,522	8,773
Total 1976-1990	9,684	1,079	8,605



Graph V-4. Chlorofluorocarbon Quantity Losses.
Source: JACA estimates.

The Derived Demand for Precursor Chemicals, 1975 to 1985

The demand for all chemicals that are precursors to CFCs can be derived from the demand for CFCs by means of chemical factors. For this purpose, factors reported by Wolf [99] and Palmer [59] are used. The scope of chemicals covered is fairly broad, although not exhaustive of all precursor chemicals. Quantities lost due to regulation are estimated for these precursor chemicals:

- Hydrofluoric acid (HF)
- Carbon tetrachloride (CCl_4)
- Fluorspar (CaF_2)

- Sulfuric acid (H_2SO_4)
- Sulfur
- Chlorine (Cl_2)
- Methane (CH_4)
- Carbon disulfide (CS_2)
- Propylene (C_3H_6).

Table V-18 summarizes the chemical processes used to produce CFC-11 and CFC-12.

Correctly estimating the derived demand for precursor chemicals with and without regulation is complicated by the fact that different proportions of CFC-11 and CFC-12 are used with regulation than would have been used in the absence of regulation because the propellant used by exempt commodities is primarily CFC-12. Because of this complication, the estimates of the demand, 1975 to 1990, for precursor chemicals both with and without regulation are preceded by a table outlining the ratios of the two CFCs and of the precursor chemicals.

The changing mix of CFC-11 and CFC-12 after the introduction of regulations, as well as the implications of this for HF and CCl_4, are summarized in Table V-19. The quantity estimates are then summarized, by chemical and by year, for demand with regulation. This summary is in Table V-20.

The two tables related to the estimates of demand for precursor chemicals in the absence of regulation are Table V-21, which gives the assumptions about the chemical ratios based upon the mix between CFC-11 and CFC-12, and Table V-22, which gives the estimates of demand in the absence of regulation, 1975 to 1990, by chemical. The ratio of CFC-11 to CFC-12 is estimated to be .58 prior to regulation. That ratio is assumed to have remained constant in the absence of regulation.

Summary: The Precursor Chemical "Wedge", 1975 to 1990

The difference between the demand for precursor chemicals in the absence of regulation and demand with regulation is summarized in Tables V-23 through V-31. Data for each precursor chemical are summarized, by year, in a separate table.

Table V-18

CHEMICAL PROCESSES FOR PRODUCING CFCS[a]

1. The chemical equations for producing CFC-11 and CFC-12 are:

   1. $CCl_4 + HF \longrightarrow HCl + CCl_3F$, for CFC-11
   2. $CCl_4 + 2HF \longrightarrow 2HCl + CCl_2F_2$, for CFC-12

   Hydrochloric acid (HCl) is a by-product of both processes.

2. Thus, for either CFC-11 or CFC-12, the immediate precursor chemicals are carbon tetrachloride (CCl_4) and anhydrous hydrogen fluoride, that is, hydrofluoric acid (HF).

3. CCl_4 is produced by one of three processes:

   1. $aC_3H_6 + (7a-2b)\ Cl_2 \longrightarrow (a-2b)\ CCl_4 + (a+b)\ C_2Cl_4 + 6aHCl$
   2. $CS_2 + 2Cl_2 \longrightarrow CCl_4 + 2S$
   3. $CH_4 + 2Cl_2 + O_2 \longrightarrow CCl_4 + 2H_2O$

   Each process requires chlorine (Cl_2). Otherwise they differ. The first process uses propylene (C_3H_6) and produces both CCl_4 and perchloroethylene (C_2Cl_4). The second process uses carbon disulfide (CS_2). The third uses methane (CH_4) and oxygen (O_2).

4. HF is produced by this process:

   $CaF_2 + H_2SO_4 \longrightarrow 2HF + CaSO_4$

   Thus, fluorspar (CaF_2) and sulfuric acid (H_2SO_4) are essential materials in production of HF.

[a] Source: Wolf [99].

Table V-19

ASSUMPTIONS ABOUT CFCS AND CHEMICAL RATIOS WITH REGULATION*

Year	Ratio of CFC-11 to CFC-12	Weighted Average Ratio of Pounds of Precursor to Pounds of CFCs	
		HF	CCl_4
1975	.58	.230	1.206
1976	.50	.245	1.220
1977	.40	.264	1.236
1978	.20	.302	1.268
1979	.02	.336	1.297

*Given the assumption that exemptions will continue at present levels to 1990, the coefficients for 1979 apply to the period 1980 to 1990.

Source of Coefficients: Palmer [59, p. 259].

Sources of the Changing Mix: Wolf [99] and industry.

Table V-20

THE ACTUAL DEMAND FOR CFCS AND PRECURSOR CHEMICALS WITH REGULATION*

(Millions of Pounds)

Year	CFCs[a]	HF[b]	CCl_4[b]	CaF_2[c]	H_2SO_4[d]	Sulfur[e]	Cl_2[f]	CH_4[g]	CS_2[h]	C_3H_6[i]
1975	443	102	534	230	306	110	774	13	107	43
1976	420	103	512	232	309	111	742	13	102	41
1977	242	64	299	144	192	69	434	7	60	24
1978	165	50	209	113	150	54	303	5	42	17
1979	21	7	27	16	21	8	39	1	5	2

*Given the assumption that the 21 million pounds of CFCs that were produced for aerosols will continue at that level until 1990, the values for 1979 can be repeated for each year, 1980 to 1990.

[a] Output of CFCs from Table V-14.

[b] Assumptions about the ratios of pounds of HF and CCl_4 to pounds of CFCs from the previous table.

[c] 2.25 times HF value.

[d] 3 times HF value.

[e] 0.36 times H_2SO_4.

[f] 1.45 times CCl_4 value.

[g] 0.025 times CCl_4 value.

[h] 0.20 times CCl_4 value.

[i] 0.08 times CCl_4 value.

Sources: Palmer [59], Wolf [99], and industry.

Table V-21

ASSUMPTIONS ABOUT CHEMICAL RATIOS WITHOUT REGULATION

Chemical	Assumption
CFC-11/CFC-12	0.58 percent
CCl_4	1.206 pounds for 1 pound of CFC[a]
HF	0.230 pounds for 1 pound of CFC[b]
Cl_2	1.45 pound of Cl_2 for 1 pound of CCl_4
CaF_2	2.25 pounds of CaF_2 for 1 pound of HF
H_2SO_4	3 pounds of H_2SO_4 for 1 pound of HF
Sulfur	0.36 pounds of sulfur for 1 pound of H_2SO_4
CH_4	0.112 pounds of CH_4 for 1 pound of CCl_4 times 0.23[c] = 0.025
CS_2	0.52 pounds of CS_2 for 1 pound of CCl_4 times 0.38[d] = 0.20
C_3H_6	0.20 pounds of C_3H_6 for 1 pound of CCl_4 times 0.39[e] = 0.08

[a] Based on [(1.14 x 0.58) + (1.30 x 0.42)]

[b] Based on [(0.15 x 0.58) + (0.34 x 0.42)]

[c] Of the three processes for making CCl_4, CH_4 is used in the one which makes 23% of the total CCl_4 produced. This factor is based on that relationship.

[d] Of the three processes for making CCl_4, CS_2 is used in the one which makes 38% of the total CCl_4 produced. This factor is based on that relationship.

[e] Of the three processes for making CCl_4, C_3H_6 is used in the one which makes 39% of the total CCl_4 produced. This factor is based on that relationship.

Sources: Palmer [59], Wolf [99], and industry.

Table V-22

DEMAND FOR CFCS AND PRECURSOR CHEMICALS WITHOUT REGULATION

(Millions of Pounds)

Year	CFCs[a]	HF[b]	CCl_4[c]	CaF_2[d]	H_2SO_4[e]	Sulfur[f]	Cl_2[g]	CH_4[h]	CS_2[i]	C_3H_6[j]
1975	611	140	737	315	420	151	1069	18	148	59
1976	644	148	777	333	444	160	1127	19	155	62
1977	666	153	803	344	459	165	1164	20	161	64
1978	677	156	816	351	468	168	1183	20	163	65
1979	728	167	878	376	501	180	1273	22	176	70
1980	710	163	856	367	489	176	1241	21	171	68
1981	696	160	839	360	480	173	1217	21	168	67
1982	680	156	820	351	468	168	1189	21	164	66
1983	669	154	807	347	462	166	1170	20	161	65
1984	652	150	786	338	450	162	1140	20	157	63
1985	640	147	772	331	441	159	1119	19	154	62
1986	621	143	749	321	428	154	1086	19	150	60
1987	602	139	727	311	415	149	1054	18	145	58
1988	548	135	705	302	402	144	1022	18	141	56
1989	566	131	684	293	390	140	922	17	137	55
1990	549	127	663	284	378	136	961	17	133	53

[a] From Table IV-16, demand for CFCs as aerosol propellants in the absence of regulation.

[b] 0.230 times CFC value.

[c] 1.206 times CFC value.

[d] 2.25 times HF value.

[e] 3 times HF value.

[f] 0.36 times H_2SO_4 value.

[g] 1.45 times CCl_4 value.

[h] 0.025 times CCl_4 value.

[i] 0.20 times CCl_4 value.

[j] 0.08 times CCl_4 value.

Sources: Palmer [59], Wolf [99], and industry.

Table V-23

THE CHEMICAL WEDGE: HYDROFLUORIC ACID (HF), 1975 TO 1990

(Millions of Pounds)

Year	Output Without Regulation[a]	Output With Regulation[b]	Difference
1975	140	102	38
1976	148	103	45
1977	153	64	89
1978	156	50	106
1979	167	7	160
1980	163	7	156
1981	160	7	153
1982	156	7	149
1983	154	7	147
1984	150	7	143
1985	147	7	140
1986	143	7	136
1987	139	7	132
1988	135	7	128
1989	131	7	124
1990	127	7	120
Total 1975-1990	2,369	403	1,966
Total 1976-1990	2,229	301	1,928

[a] Output in the absence of regulation follows from Table V-16 (demand for CFCs for use as aerosol propellants in the absence of regulation) and Table V-21 (assumptions about chemical factors relating CFC use to precursor chemical use, by chemical).

[b] Output with regulation is based on actual output of CFCs, 1975 to 1979, the assumption that exemptions will continue to use 21 million pounds per year of CFCs, and chemical factors in Table V-19.

Table V-24

THE CHEMICAL WEDGE: CARBON TETRACHLORIDE (CCl_4), 1975 TO 1990

(Millions of Pounds)

Year	Output Without Regulation[a]	Output With Regulation[b]	Difference
1975	737	534	203
1976	777	512	265
1977	803	299	504
1978	816	209	607
1979	878	27	851
1980	856	27	829
1981	839	27	812
1982	820	27	793
1983	807	27	780
1984	786	27	759
1985	772	27	745
1986	749	27	722
1987	727	27	700
1988	705	27	678
1989	684	27	657
1990	663	27	636
Total 1975-1990	12,419	1,878	10,541
Total 1976-1990	11,682	1,344	10,338

[a] Output in the absence of regulation follows from Table V-16 (demand for CFCs for use as aerosol propellants in the absence of regulation) and Table V-21 (assumptions about chemical factors relating CFC use to precursor chemical use, by chemical).

[b] Output with regulation is based on actual output of CFCs, 1975 to 1979, the assumption that exemptions will continue to use 21 million pounds per year of CFCs, and chemical factors in Table V-19.

Table V-25

THE CHEMICAL WEDGE: FLUORSPAR (CaF_2), 1975 TO 1990

(Millions of Pounds)

Year	Output Without Regulation[a]	Output With Regulation[b]	Difference
1975	315	230	85
1976	333	232	101
1977	344	144	200
1978	351	113	238
1979	376	16	360
1980	367	16	351
1981	360	16	344
1982	351	16	335
1983	347	16	331
1984	338	16	322
1985	331	16	315
1986	321	16	305
1987	311	16	295
1988	302	16	286
1989	293	16	277
1990	284	16	268
Total 1975-1990	5,324	911	4,413
Total 1976-1990	5,009	681	4,328

[a] Output in the absence of regulation follows from Table V-16 (demand for CFCs for use as aerosol propellants in the absence of regulation) and Table V-21 (assumptions about chemical factors relating CFC use to precursor chemical use, by chemical).

[b] Output with regulation is based on actual output of CFCs, 1975 to 1979, the assumption that exemptions will continue to use 21 million pounds per year of CFCs, and chemical factors in Table V-19.

Table V-26

THE CHEMICAL WEDGE: SULFURIC ACID (H_2SO_4), 1975 TO 1990

(Millions of Pounds)

Year	Output Without Regulation[a]	Output With Regulation[b]	Difference
1975	420	306	114
1976	444	309	135
1977	459	192	267
1978	468	150	318
1979	501	21	480
1980	489	21	468
1981	480	21	459
1982	468	21	447
1983	462	21	441
1984	450	21	429
1985	441	21	420
1986	428	21	407
1987	415	21	394
1988	402	21	381
1989	390	21	369
1990	378	21	357
Total 1975-1990	7,095	1,209	5,886
Total 1976-1990	6,675	903	5,772

[a] Output in the absence of regulation follows from Table V-16 (demand for CFCs for use as aerosol propellants in the absence of regulation) and Table V-21 (assumptions about chemical factors relating CFC use to precursor chemical use, by chemical).

[b] Output with regulation is based on actual output of CFCs, 1975 to 1979, the assumption that exemptions will continue to use 21 million pounds per year of CFCs, and chemical factors in Table V-19.

Table V-27

THE CHEMICAL WEDGE: SULFUR, 1975 TO 1990

(Millions of Pounds)

Year	Output Without Regulation[a]	Output With Regulation[b]	Difference
1975	151	110	41
1976	160	111	49
1977	165	69	96
1978	168	54	114
1979	180	8	172
1980	176	8	168
1981	173	8	165
1982	168	8	160
1983	166	8	158
1984	162	8	154
1985	159	8	151
1986	154	8	146
1987	149	8	141
1988	144	8	136
1989	140	8	132
1990	136	8	128
Total 1975-1990	2,551	440	2,111
Total 1976-1990	2,400	330	2,070

[a] Output in the absence of regulation follows from Table V-16 (demand for CFCs for use as aerosol propellants in the absence of regulation) and Table V-21 (assumptions about chemical factors relating CFC use to precursor chemical use, by chemical).

[b] Output with regulation is based on actual output of CFCs, 1975 to 1979, the assumption that exemptions will continue to use 21 million pounds per year of CFCs, and chemical factors in Table V-19.

Table V-28

THE CHEMICAL WEDGE: CHLORINE (Cl_2), 1975 TO 1990

(Millions of Pounds)

Year	Output Without Regulation[a]	Output With Regulation[b]	Difference
1975	1,069	774	295
1976	1,127	742	385
1977	1,164	434	730
1978	1,183	303	880
1979	1,273	39	1,234
1980	1,241	39	1,202
1981	1,217	39	1,178
1982	1,189	39	1,150
1983	1,170	39	1,131
1984	1,140	39	1,101
1985	1,119	39	1,080
1986	1,086	39	1,047
1987	1,054	39	1,015
1988	1,022	39	983
1989	992	39	953
1990	961	39	922
Total 1975-1990	18,007	2,721	15,286
Total 1976-1990	16,938	1,947	14,991

[a] Output in the absence of regulation follows from Table V-16 (demand for CFCs for use as aerosol propellants in the absence of regulation) and Table V-21 (assumptions about chemical factors relating CFC use to precursor chemical use, by chemical).

[b] Output with regulation is based on actual output of CFCs, 1975 to 1979, the assumption that exemptions will continue to use 21 million pounds per year of CFCs, and chemical factors in Table V-19.

Table V-29

THE CHEMICAL WEDGE: METHANE (CH_4), 1975 TO 1990

(In Millions of Pounds)

Year	Output Without Regulation[a]	Output With Regulation[b]	Difference
1975	18	13	5
1976	19	13	6
1977	20	7	13
1978	20	5	15
1979	22	1	21
1980	21	1	20
1981	21	1	20
1982	21	1	20
1983	20	1	19
1984	20	1	19
1985	19	1	18
1986	19	1	18
1987	18	1	17
1988	18	1	17
1989	17	1	16
1990	17	1	16
Total 1975-1990	310	50	260
Total 1976-1990	292	37	255

[a] Output in the absence of regulation follows from Table V-16 (demand for CFCs for use as aerosol propellants in the absence of regulation) and Table V-21 (assumptions about chemical factors relating CFC use to precursor chemical use, by chemical).

[b] Output with regulation is based on actual output of CFCs, 1975 to 1979, the assumption that exemptions will continue to use 21 million pounds per year of CFCs, and chemical factors in Table V-19.

Table V-30

THE CHEMICAL WEDGE: PROPYLENE (C_3H_6), 1975 TO 1990

(In Millions of Pounds)

Year	Output Without Regulation[a]	Output With Regulation[b]	Difference
1975	59	43	16
1976	62	41	21
1977	64	24	40
1978	65	17	48
1979	70	2	68
1980	68	2	66
1981	67	2	65
1982	66	2	64
1983	65	2	63
1984	63	2	61
1985	62	2	60
1986	60	2	58
1987	58	2	56
1988	56	2	54
1989	55	2	53
1990	53	2	51
Total 1975-1990	993	149	844
Total 1976-1990	934	106	828

[a] Output in the absence of regulation follows from Table V-16 (demand for CFCs for use as aerosol propellants in the absence of regulation) and Table V-21 (assumptions about chemical factors relating CFC use to precursor chemical use, by chemical).

[b] Output with regulation is based on actual output of CFCs, 1975 to 1979, the assumption that exemptions will continue to use 21 million pounds per year of CFCs, and chemical factors in Table V-19.

Table V-31

THE CHEMICAL WEDGE: CARBON DISULFIDE (CS_2), 1975 TO 1990

(In Millions of Pounds)

Year	Output Without Regulation[a]	Output With Regulation[b]	Difference
1975	148	107	41
1976	155	102	53
1977	161	60	101
1978	163	42	121
1979	176	5	171
1980	171	5	166
1981	168	5	163
1982	164	5	159
1983	161	5	156
1984	157	5	152
1985	154	5	149
1986	150	5	145
1987	145	5	140
1988	141	5	136
1989	137	5	132
1990	133	5	128
Total 1975-1990	2,484	371	2,113
Total 1976-1990	2,336	264	2,072

[a] Output in the absence of regulation follows from Table V-16 (demand for CFCs for use as aerosol propellants in the absence of regulation) and Table V-21 (assumptions about chemical factors relating CFC use to precursor chemical use, by chemical).

[b] Output with regulation is based on actual output of CFCs, 1975 to 1979, the assumption that exemptions will continue to use 21 million pounds per year of CFCs, and chemical factors in Table V-19.

TOTAL QUANTITY LOSSES

The summary of the total quantity losses for the producers of both aerosols and chemicals from 1975 to 1990 is in Table V-32. These quantity losses are only one measure of economic impact. In the next chapter, the implications of these quantity losses on profits are evaluated for each of the industries in the aerosol and chemical sectors.

Table V-32

QUANTITY LOSSES IN THE AEROSOL AND CHEMICAL SECTORS, 1975 TO 1990

Sector	Quantity Losses Due to Regulation
Aerosols	
	(Billions of Units)
Containers	25.8
Valves	25.8
Filling	25.8
Chemicals	
	(Billions of Pounds)
CFCs	8.8
Hydrofluoric Acid	2.0
Carbon Tetrachloride	10.5
Fluorspar	4.4
Sulfuric Acid	5.9
Sulfur	2.1
Chlorine	15.3
Methane	0.3
Carbon Disulfide	2.1
Propylene	0.8

Chapter VI

ECONOMIC IMPACT ON PRODUCERS' PROFITS

The impact of the quantity losses discussed in the last chapter on the profits of aerosol and chemical producers can be estimated as the net present value (NPV) of profit streams foregone. Using this measure of profit impact, it is possible to include information about changes in the profit flows of firms or plants that remain in existence, as well as those that withdrew from the industry as a result of regulation.* The lost profit streams are estimated in 1976 dollars in order to allow some comparisons between this study and the IR&T report [36],** which was the economic support document used at the time of regulation.

The lost profit streams are the major real resource cost of this regulation to the U.S. economy. This is because the profits before taxes from CFC products affected by regulation were lost to society. Specifically, the capital equipment that existed prior to regulation in the chemical and aerosol sectors was dedicated (nontransferrable to other uses) and became unemployed due to regulation. As a result, the income -- both profits and taxes -- that could have been generated by this equipment was not generated, thus reducing the net national product (NNP) of the U.S. economy. NNP, viewed from the income side, is the sum of wages, taxes, depreciation, and profits (both retained and distributed). The assumption in this report is that labor (or lost wages in the affected sector) was transferrable, and therefore that there was no additional impact from labor on NNP. It is also assumed that all raw materials, such as steel for metal aerosol containers, could also be utilized elsewhere.

In addition to these direct effects, there are secondary effects of the regulation on other sectors in the U.S. economy. Something can be said of the positive secondary effects of the decreased sales of aerosol products on other sectors. Positive secondary effects of regulation are gains by other sectors in the U.S. economy as a result of regulation-induced declines in primary sectors. An example of positive secondary effects is gains in nonaerosol sales that resulted from decreased aerosol sales plus gains in sales of raw materials that supply the nonaerosol sector. For example, in the case of aerosol antiperspirants, loss of aerosol sales may have been partially or totally offset by gains in nonaerosol antiperspirants and these related industries: nonaerosol filling, nonaerosol containers, nonaerosol caps and closures, concentrate suppliers, and shipping package manufacturers. The effects of these secondary effects is explicitly considered in this report only for marketers. In the case of marketers, the strong presumption is made that gains in marketers' sales of their nonaerosol products canceled out marketers' losses from aerosol sales.

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*For a discussion of an alternative measure of economic impact on profits, namely, changes in profit rates, see Appendix C.

**The comparison of these results with IR&T, as required by the contract, is in Chapter XIV.

The reason for not calculating secondary offsets explicitly for all sectors is largely grounded in analytic issues related to the capital stock involved in the two situations: lost aerosol sales "versus" increased nonaerosol sales. Lost aerosol sales resulted in capital becoming unusable. Increased nonaerosol sales, on the other hand, resulted in not only the use of capital that had previously been unemployed* but also the construction of new capital. To meet investment needs for new capital in the nonaerosol sector, companies would have had to bid transferrable resources away from all other sectors in the economy. In the absence of information to the contrary, it is reasonable to suppose that the profits generated on this new capital equipment to meet the increased demand for these substitute nonaerosol products is not significantly larger than its return would have been elsewhere in the economy. Hence, in the absence of supernormal profits in the nonaerosol sector relative to the rest of the economy, it would be incorrect to subtract any portion of profits generated by this new capital equipment in the nonaerosol sector from the profits lost in the aerosol sector.

THE AEROSOL AND CHEMICAL SECTORS

In order to translate the lost output due to regulation that was reported in the previous chapter into discounted profits foregone, in 1976 dollars, additional information is required for each of three aerosol industries and the ten chemical industries. This information includes the 1976 price of each product (in order to obtain value of shipments) and the ratio of profits to sales (in order to obtain profits foregone). A real discount rate must be chosen in order to calculate the NPV of the profits foregone due to regulation. The choice of prices, profit rates, and the discount rate are considered in turn. After this, the impact of regulation on profits for the thirteen industries is calculated.

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*IR&T [36] estimates, for example, that only 50 million units of nonaerosol antiperspirant demand could have been met beyond 1976 with existing nonaerosol filling capacity.

The Measure of Price

Price is an estimated average price paid in 1976 for the product of each sector, be it a container or a CFC. For the chemical sectors, the data source for this report was the average price paid for a chemical, as reported by the U.S. International Trade Commission [95]. For the aerosol sector, average prices paid are not published and therefore were obtained from industry. The prices for the aerosol sector are similar to those in the IR&T report [36].*

- For containers, the average price paid for a metal aerosol container is 13.5 cents per unit in 1976. (This conforms with data in IR&T [36, Table 2.15].)
- For valves, the average price paid is 5 cents per unit for a valve and actuator in 1976. (This is lower than the IR&T estimate.)
- For fillers, the average price paid for filling services was 59 cents per unit filled in 1976.

The Measure of Profit Rates

The profit rate is the ratio of before tax profits, net of depreciation, to sales. Actual profit rates are used for each year, 1975 to 1979, and an unweighted average of the 1975 to 1979 rates is used for 1980 and thereafter. This is done to obtain an average value over the most recent business cycle.

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*Census does not report sufficient information at the 8-digit level to obtain information for: aerosol containers; aerosol valves, caps, and actuators; aerosol filling (business services not elsewhere classified); or various chemicals.

The analytic choice is between profits net of depreciation before taxes, and profits net of depreciation after taxes. A before tax profits figure is used in order to include the costs to industry and the lost tax revenue to government. The measure of loss should cover output lost regardless of the recipient of the output's value, because one wishes to evaluate the impact of regulation on the NNP. Profits are measured net of depreciation in cases such as this in order to conform to NNP, which is gross national product (GNP) minus depreciation.*

The choice of a data source for profits before taxes on sales is largely dictated by the availability of published data. Most of the sectors are in eight-digit Standard Industrial Classification (SIC) industries, for which Census profits data are not available. Moreover, one cannot rely on annual or 10-K reports for profits on sales data because most firms, whatever their size, are privately-owned. For firms that do have annual reports, the product-line information is buried in income statements, which makes the relevant information difficult, if not impossible, to extract.

Four-digit data on before tax profits on sales, published by Robert Morris Associates [66], are used for these sectors:

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*Profits net of depreciation rather than gross of depreciation are used as the measure of the loss in social welfare due to regulation. In this context, depreciation is an approximation of the amount of resources required to maintain a level of capital unchanged from the beginning to the end of the period, and this amount must be subtracted from gross output. It is output net of depreciation that constituted the contribution of the aerosol and chemical sectors to the welfare of society before the ban, and it is this net output that was lost due to the ban. Since the replacement of capital needed by these industries to maintain their capital stock is no longer required by these industries after regulation, the resources that would have been devoted to this purpose are available for use elsewhere in society.

EPA does not agree with this choice of profits net of depreciation. EPA believes that depreciation is an operating expense which serves to set aside funds for future purchases of capital. When income falls to zero, this fund is no longer available. The loss to society should include the loss of this revenue. Hence, EPA believes that JACA has underestimated the economic impact by the amount of depreciation.

- Aerosol containers (metal and glass), SIC 3411 (metal cans)
- Aerosol valves and actuators, SIC 3499 (miscellaneous nonferrous fabricated products)
- Fillers, the figures for filling equipment (not filling, which is business services elsewhere classified), SIC 3561 (general industrial machinery and equipment)
- Chemicals, SICs 2961, 2864, and 2869 (industrial chemicals).

The Real Discount Rate

An appropriate discount rate for industry is one which takes into account the greater risk of investment to industry relative to the Federal government. Within that broad range, an appropriate discount rate is obtained by:

$$(\text{Dividend/Price}) \times 2$$

The dividend/price ratio is multiplied by 2 to reflect the fact that approximately one-half of profits are withheld by corporations as retained earnings. The actual measure used as a discount rate is from Standard and Poor's composite yield (500 stocks) for 1975 to 1979, as reported by BEA [77,78]. The results are in Table VI-1. The real discount rate is, thus, 9.37 percent.*

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*9.37 percent is the earnings-price ratio in the base period, and therefore it is a real rate (adjusted for inflation). To see this, suppose that the price of a share of corporate equity is V, and earnings associated with this share at the beginning of the period is X. With an inflation rate of p, the earnings expected to accrue at a time, t (measuring time with the percent as the origin), is Xe^{pt}. The earnings stream is thus expected to increase with inflation. Let the nominal rate of discount be r. Then, the price of the share, V, which must be equal to the present value of the earnings stream is given by:

$$V = \int_0^\infty e^{-rt}\, Xe^{pt}\, dt = X \int_0^\infty e^{-(r-p)t}\, dt = X \frac{1}{r-p}$$

Therefore, the earnings-price ratio, $\frac{X}{V}$, is $\frac{X}{V} = r-p$

showing that the earnings-price ratio is a real, rather than a nominal rate.

Table VI-1

THE REAL DISCOUNT RATE

(Percent)

Year	Dividend/Price S&P's 500 Stocks	Discount Rate (Dividend/Price) x 2
1975	4.31	8.62
1976	3.77	7.54
1977	4.62	9.24
1978	5.29	10.58
1979	5.45	10.90
Average, 1975-1979	4.68	9.37

Source: Bureau of Economic Analysis [77,78].

There is a straightforward reason for this choice of a real discount rate. One measure of the loss to society is the stream of profits associated with capital equipment that existed in the chemical and aerosol sectors at the time of the ban. Consumers, by their behavior in the stock market, specify the rate of discount that they deem appropriate to use for this source of income.

This approach is consistent with the conclusions of Bailey and others, as reported in Palmer [59, p. 33]. More specifically, Palmer assumes a real discount rate of 11 percent a year, based on 1979 estimates of "the current real yield on nonconstruction investment in the United States." The rate in this study for 1979 is 5.45 x 2, which is approximately equal to Palmer's real rate of 11 percent, also for 1979.

Profit Streams Foregone

The results of calculations based on these measures of price, profit rates, and discount rates are summarized by industry and year for 1975 to 1990 in Tables VI-2 through VI-14. In each table, the following information is reported annually:

- The estimate of the quantity wedge, defined as lost output or the difference between demand with and without regulation

Table VI-2

PROFIT STREAMS FOREGONE IN AEROSOL CONTAINER INDUSTRY

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	893	.135	120.6	.055	6.63	7.25
1976	1,224	.135	165.2	.017	2.81	2.81
1977	1,592	.135	214.9	.052	11.17	10.21
1978	1,704	.135	230.0	.048	11.04	9.23
1979	1,962	.135	264.9	.069	18.28	13.97
1980	2,238	.135	302.1	.048	14.50	10.13
1981	2,239	.135	302.3	.048	14.51	9.27
1982	2,239	.135	302.3	.048	14.51	8.48
1983	2,240	.135	302.4	.048	14.52	7.76
1984	2,239	.135	302.3	.048	14.51	7.09
1985	2,238	.135	302.1	.048	14.50	6.48
1986	2,000	.135	270.0	.048	12.96	5.29
1987	1,500	.135	202.5	.048	9.72	3.63
1988	1,000	.135	135.0	.048	6.48	2.21
1989	500	.135	67.5	.048	3.24	1.01
1990	0	.135	0.0	.048	0.00	0.00
Total 1975 to 1990	25,808		3,484.1		169.38	104.82
Total 1976 to 1990	24,915		3,363.5		162.75	97.57

[a] Based on estimates of the difference between demand with and without regulation, 1975 to 1990 (see Chapter V on quantities lost in the aerosol sector).

[b] Price is an average price paid in 1976. In the case of aerosol containers, the price of 13.5¢ a piece is used.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] Average profits on sales are actual numbers, 1975 to 1979, for profits before taxes over sales for the relevant four-digit industries; the average over the business cycle, 1975 to 1979, was applied to VS data, 1980 to 1990. Source of profits data: Robert Morris Associates [66]. For an explanation of why this profit rate was selected, see the text.

[e] The profit stream foregone is VS x the profit rate (column d).

[f] The discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P's stocks for 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-3

PROFIT STREAMS FOREGONE IN AEROSOL VALVE INDUSTRY

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	893	.05	44.65	.065	2.90	3.17
1976	1,224	.05	61.20	.061	3.73	3.73
1977	1,592	.05	79.60	.054	4.30	3.93
1978	1,704	.05	85.20	.053	4.52	3.78
1979	1,962	.05	98.10	.058	5.69	4.35
1980	2,238	.05	111.90	.058	6.49	4.54
1981	2,239	.05	111.95	.058	6.49	4.15
1982	2,239	.05	111.95	.058	6.49	3.79
1983	2,240	.05	112.00	.058	6.50	3.47
1984	2,239	.05	111.95	.058	6.49	3.17
1985	2,238	.05	111.90	.058	6.49	2.90
1986	2,000	.05	100.00	.058	5.80	2.37
1987	1,500	.05	75.00	.058	4.35	1.62
1988	1,000	.05	50.00	.058	2.90	0.99
1989	500	.05	25.00	.058	1.45	0.45
1990	0	.05	0.00	.058	0.00	0.00
Total 1975 to 1990	25,808		1,290.40		74.59	46.41
Total 1976 to 1990	24,915		1,245.75		71.69	43.24

[a] Based on estimates of the difference between demand with and without regulation, 1975 to 1990 (see Chapter V on quantities lost in the aerosol sector).

[b] Price is an average price paid in 1976. In the case of valves, actuators, and closures, the cost is estimated to be 5¢ a container.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] Average profits on sales are actual numbers, 1975 to 1979, for profits before taxes over sales for the relevant four-digit industries; the average over the business cycle, 1975 to 1979, was applied to VS data, 1980 to 1990. Source of profits data: Robert Morris Associates [66]. For an explanation of why this profit rate was selected, see the text.

[e] The profit stream foregone is VS x the profit rate (column d).

[f] The discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P's stocks for 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-4

PROFIT STREAMS FOREGONE IN AEROSOL FILLING INDUSTRY

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	893	.59	526.9	.088	46.37	50.71
1976	1,224	.59	722.2	.063	45.50	45.50
1977	1,592	.59	939.3	.061	57.30	52.39
1978	1,704	.59	1,005.4	.060	60.32	50.43
1979	1,962	.59	1,157.6	.067	77.56	59.28
1980	2,238	.59	1,320.4	.068	89.79	62.75
1981	2,239	.59	1,321.0	.068	89.83	57.40
1982	2,239	.59	1,321.0	.068	89.83	52.48
1983	2,240	.59	1,321.6	.068	89.87	48.01
1984	2,239	.59	1,321.0	.068	89.83	43.88
1985	2,238	.59	1,320.4	.068	89.79	40.10
1986	2,000	.59	1,180.0	.068	80.24	32.76
1987	1,500	.59	885.0	.068	60.18	22.47
1988	1,000	.59	590.0	.068	40.12	13.70
1989	500	.59	295.0	.068	20.06	6.26
1990	0	.59	0.0	.068	0.00	0.00
Total 1975 to 1990	25,808		15,226.8		1,026.59	638.12
Total 1976 to 1990	24,915		14,699.9		980.22	587.41

[a] Based on estimates of the difference between demand with and without regulation, 1975 to 1990 (see Chapter V on quantities lost in the aerosol sector).

[b] Price is an average price paid in 1976. The estimated filling cost is 59¢ per unit, based on large orders of a "typical" 8-ounce HC product.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] Average profits on sales are actual numbers, 1975 to 1979, for profits before taxes over sales for the relevant four-digit industries; the average over the business cycle, 1975 to 1979, was applied to VS data, 1980 to 1990. Source of profits data: Robert Morris Associates [66]. For an explanation of why this profit rate was selected, see the text.

[e] The profit stream foregone is VS x the profit rate (column d).

[f] The discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P's stocks for 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-5

PROFIT STREAMS FOREGONE BY CFC PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	168	.37	62.2	.091	5.66	6.19
1976	224	.37	82.9	.077	6.38	6.38
1977	424	.37	156.9	.065	10.20	9.33
1978	512	.37	189.4	.057	10.80	9.03
1979	707	.37	261.6	.057	14.91	11.40
1980	689	.37	254.9	.069	17.59	12.29
1981	675	.37	249.7	.069	17.23	11.01
1982	659	.37	243.8	.069	16.82	9.83
1983	648	.37	239.8	.069	16.55	8.84
1984	631	.37	233.5	.069	16.11	7.87
1985	619	.37	229.0	.069	15.80	7.06
1986	600	.37	222.0	.069	15.32	6.26
1987	581	.37	215.0	.069	14.84	5.54
1988	563	.37	208.3	.069	14.37	4.91
1989	545	.37	201.7	.069	13.92	4.34
1990	528	.37	195.4	.069	13.48	3.85
Total 1975 to 1990	8,773		3,246.1		219.98	124.13
Total 1976 to 1990	8,605		3,183.9		214.32	117.94

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. In the case of CFCs, it is a weighted average of 1976 prices, namely, [(Price of CFC-11 x .58) + (Price of CFC-12 x .42)].

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-6

PROFIT STREAMS FOREGONE BY HYDROFLUORIC ACID (HF) PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	38	.334	12.69	.091	1.15	1.26
1976	45	.334	15.03	.077	1.16	1.16
1977	89	.334	29.73	.065	1.93	1.76
1978	106	.334	35.40	.057	2.02	1.69
1979	160	.334	53.44	.057	3.05	2.33
1980	156	.334	52.10	.069	3.59	2.51
1981	153	.334	51.10	.069	3.53	2.26
1982	149	.334	49.77	.069	3.43	2.00
1983	147	.334	49.10	.069	3.39	1.81
1984	143	.334	47.76	.069	3.30	1.61
1985	140	.334	46.76	.069	3.23	1.44
1986	136	.334	45.42	.069	3.13	1.28
1987	132	.334	44.09	.069	3.04	1.13
1988	128	.334	42.75	.069	2.95	1.01
1989	124	.334	41.42	.069	2.86	0.89
1990	120	.334	40.08	.069	2.77	0.79
Total 1975 to 1990	1,966		656.64		44.53	24.93
Total 1976 to 1990	1,928		643.95		43.38	23.67

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. Sources of 1976 price data: the U.S. International Trade Commission and the U.S. Bureau of Mines.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-7

PROFIT STREAMS FOREGONE BY CARBON TETRACHLORIDE (CCl_4) PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	203	.130	26.39	.091	2.40	2.62
1976	265	.130	34.45	.077	2.65	2.65
1977	504	.130	65.52	.065	4.26	3.90
1978	607	.130	78.91	.057	4.50	3.76
1979	851	.130	110.63	.057	6.31	4.82
1980	829	.130	107.77	.069	7.44	5.20
1981	812	.130	105.56	.069	7.28	4.65
1982	793	.130	103.09	.069	7.11	4.15
1983	780	.130	101.40	.069	7.00	3.74
1984	759	.130	98.67	.069	6.81	3.33
1985	745	.130	96.85	.069	6.68	2.98
1986	722	.130	93.86	.069	6.48	2.65
1987	700	.130	91.00	.069	6.28	2.34
1988	678	.130	88.14	.069	6.08	2.08
1989	657	.130	85.41	.069	5.89	1.84
1990	636	.130	82.68	.069	5.70	1.63
Total 1975 to 1990	10,541		1,370.33		92.87	52.34
Total 1976 to 1990	10,338		1,343.94		90.47	49.72

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. Sources of 1976 price data: the U.S. International Trade Commission and the U.S. Bureau of Mines.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-8

PROFIT STREAMS FOREGONE BY FLUORSPAR (CaF_2) PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	85	.054	4.59	.091	0.42	0.46
1976	101	.054	5.45	.077	0.42	0.42
1977	200	.054	10.80	.065	0.70	0.64
1978	238	.054	12.85	.057	0.73	0.61
1979	360	.054	19.44	.057	1.11	0.85
1980	351	.054	18.95	.069	1.31	0.92
1981	344	.054	18.58	.069	1.28	0.82
1982	335	.054	18.09	.069	1.25	0.73
1983	331	.054	17.87	.069	1.23	0.66
1984	322	.054	17.39	.069	1.20	0.59
1985	315	.054	17.01	.069	1.17	0.52
1986	305	.054	16.47	.069	1.14	0.47
1987	295	.054	15.93	.069	1.10	0.41
1988	286	.054	15.44	.069	1.07	0.37
1989	277	.054	14.96	.069	1.03	0.32
1990	268	.054	14.47	.069	1.00	0.29
Total 1975 to 1990	4,413		238.29		16.16	9.08
Total 1976 to 1990	4,328		233.70		15.74	8.62

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. Sources of 1976 price data: the U.S. International Trade Commission and the U.S. Bureau of Mines.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-9

PROFIT STREAMS FOREGONE BY SULFURIC ACID (H_2SO_4) PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	114	.016	1.82	.091	0.17	0.19
1976	135	.016	2.16	.077	0.17	0.17
1977	267	.016	4.27	.065	0.28	0.26
1978	318	.016	5.09	.057	0.29	0.24
1979	480	.016	7.68	.057	0.44	0.34
1980	468	.016	7.49	.069	0.52	0.36
1981	459	.016	7.34	.069	0.51	0.33
1982	447	.016	7.15	.069	0.49	0.29
1983	441	.016	7.06	.069	0.49	0.26
1984	429	.016	6.86	.069	0.47	0.23
1985	420	.016	6.72	.069	0.46	0.21
1986	407	.016	6.51	.069	0.45	0.18
1987	394	.016	6.30	.069	0.43	0.16
1988	381	.016	6.10	.069	0.42	0.14
1989	369	.016	5.90	.069	0.41	0.13
1990	357	.016	5.71	.069	0.39	0.11
Total 1975 to 1990	5,886		96.16		6.39	3.60
Total 1976 to 1990	5,772		94.34		6.22	3.41

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. Sources of 1976 price data: the U.S. International Trade Commission and the U.S. Bureau of Mines.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-10

PROFIT STREAMS FOREGONE BY SULFUR PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	41	.017	0.70	.091	0.06	0.07
1976	49	.017	0.83	.077	0.06	0.06
1977	96	.017	1.63	.065	0.11	0.10
1978	114	.017	1.94	.057	0.11	0.09
1979	172	.017	2.92	.057	0.17	0.13
1980	168	.017	2.86	.069	0.20	0.14
1981	165	.017	2.81	.069	0.19	0.12
1982	160	.017	2.72	.069	0.19	0.11
1983	158	.017	2.69	.069	0.19	0.10
1984	154	.017	2.62	.069	0.18	0.09
1985	151	.017	2.57	.069	0.18	0.08
1986	146	.017	2.48	.069	0.17	0.07
1987	141	.017	2.40	.069	0.17	0.06
1988	136	.017	2.31	.069	0.16	0.05
1989	132	.017	2.24	.069	0.15	0.05
1990	128	.017	2.18	.069	0.15	0.04
Total 1975 to 1990	2,111		35.90		2.44	1.36
Total 1976 to 1990	2,070		35.20		2.38	1.29

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. Sources of 1976 price data: the U.S. International Trade Commission and the U.S. Bureau of Mines.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-11

PROFIT STREAMS FOREGONE BY CHLORINE (Cl_2) PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	295	.043	12.69	.091	1.15	1.26
1976	385	.043	16.55	.077	1.27	1.27
1977	730	.043	31.39	.065	2.04	1.87
1978	880	.043	37.84	.057	2.16	1.81
1979	1,234	.043	53.06	.057	3.02	2.31
1980	1,202	.043	51.69	.069	3.57	2.50
1981	1,178	.043	50.65	.069	3.49	2.23
1982	1,150	.043	49.45	.069	3.41	1.99
1983	1,131	.043	48.63	.069	3.36	1.79
1984	1,101	.043	47.34	.069	3.27	1.60
1985	1,080	.043	46.44	.069	3.20	1.43
1986	1,047	.043	45.02	.069	3.11	1.27
1987	1,015	.043	43.65	.069	3.01	1.12
1988	983	.043	42.27	.069	2.92	1.00
1989	953	.043	40.98	.069	2.83	0.88
1990	922	.043	39.65	.069	2.74	0.78
Total 1975 to 1990	15,286		657.30		44.55	25.11
Total 1976 to 1990	14,991		644.61		43.40	23.85

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. Sources of 1976 price data: the U.S. International Trade Commission and the U.S. Bureau of Mines.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-12

PROFIT STREAMS FOREGONE BY METHANE (CH_4) PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	5	.045	0.23	.091	0.02	0.02
1976	6	.045	0.27	.077	0.02	0.02
1977	13	.045	0.59	.065	0.04	0.04
1978	15	.045	0.68	.057	0.04	0.03
1979	21	.045	0.95	.057	0.05	0.04
1980	20	.045	0.90	.069	0.06	0.04
1981	20	.045	0.90	.069	0.06	0.04
1982	20	.045	0.90	.069	0.06	0.04
1983	19	.045	0.86	.069	0.06	0.03
1984	19	.045	0.86	.069	0.06	0.03
1985	18	.045	0.81	.069	0.06	0.03
1986	18	.045	0.81	.069	0.06	0.02
1987	17	.045	0.77	.069	0.05	0.02
1988	17	.045	0.77	.069	0.05	0.02
1989	16	.045	0.72	.069	0.05	0.02
1990	16	.045	0.72	.069	0.05	0.01
Total 1975 to 1990	260		11.74		0.79	0.45
Total 1976 to 1990	255		11.51		0.77	0.43

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. Sources of 1976 price data: the U.S. International Trade Commission and the U.S. Bureau of Mines.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-13

PROFIT STREAMS FOREGONE BY CARBON DISULFIDE (CS_2) PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	41	.07	2.87	.091	0.26	0.28
1976	53	.07	3.71	.077	0.29	0.29
1977	101	.07	7.07	.065	0.46	0.42
1978	121	.07	8.47	.057	0.48	0.40
1979	171	.07	11.97	.057	0.68	0.52
1980	166	.07	11.62	.069	0.80	0.56
1981	163	.07	11.41	.069	0.79	0.50
1982	159	.07	11.13	.069	0.77	0.45
1983	156	.07	10.92	.069	0.75	0.40
1984	152	.07	10.64	.069	0.73	0.36
1985	149	.07	10.43	.069	0.72	0.32
1986	145	.07	10.15	.069	0.70	0.29
1987	140	.07	9.80	.069	0.68	0.25
1988	136	.07	9.52	.069	0.66	0.23
1989	132	.07	9.24	.069	0.64	0.20
1990	128	.07	8.96	.069	0.62	0.18
Total 1975 to 1990	2,113		147.91		10.03	5.65
Total 1976 to 1990	2,072		145.04		9.77	5.37

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. Sources of 1976 price data: the U.S. International Trade Commission and the U.S. Bureau of Mines.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

Table VI-14

PROFIT STREAMS FOREGONE BY PROPYLENE (C_3H_6) PRODUCERS

(Millions of 1976 Dollars)

Year	Lost Output[a] (Million Units)	Price[b] ($/Unit)	Value of Shipments[c]	Ratio of Profits to Sales[d]	Profits Lost[e]	Discounted Profits Foregone[f]
1975	16	.074	1.18	.091	0.11	0.12
1976	21	.074	1.55	.077	0.12	0.12
1977	40	.074	2.96	.065	0.19	0.17
1978	48	.074	3.55	.057	0.20	0.17
1979	68	.074	5.03	.057	0.29	0.22
1980	66	.074	4.88	.069	0.34	0.24
1981	65	.074	4.81	.069	0.33	0.21
1982	64	.074	4.74	.069	0.33	0.19
1983	63	.074	4.66	.069	0.32	0.17
1984	61	.074	4.51	.069	0.31	0.15
1985	60	.074	4.44	.069	0.31	0.14
1986	58	.074	4.29	.069	0.30	0.12
1987	56	.074	4.14	.069	0.30	0.11
1988	54	.074	4.00	.069	0.30	0.10
1989	53	.074	3.92	.069	0.30	0.09
1990	51	.074	3.77	.069	0.30	0.09
Total 1975 to 1990	844		62.43		4.35	2.41
Total 1976 to 1990	828		61.25		4.24	2.29

[a] Based on estimates of the difference between demand for CFCs in the absence of regulation and demand for CFCs with regulation. For precursor chemicals, the chemical factor is applied (see Chapter V on quantities lost, by chemical).

[b] Price is an average price paid in 1976. Sources of 1976 price data: the U.S. International Trade Commission and the U.S. Bureau of Mines.

[c] Value of shipments (VS) is quantity times price (column a x column b).

[d] The ratio of profits to sales is profits before taxes divided by sales for the industrial chemicals market. Actual observed data are used for each year, 1975 to 1979; an average over the business cycle, 1975 to 1979, is used for the forecast period. Source of data: Robert Morris Associates [66].

[e] VS times the ratios of profits before taxes to sales (column d).

[f] The real discount rate is estimated to be 9.37%. This is 2 times the dividend to price ratio for S&P stocks, 1975 to 1979. Profit streams are discounted back to 1976.

- The 1976 estimated average price of the product
- The lost value of shipments that results from multiplying the quantity wedge times the average price of the product
- The ratio of before tax profits on sales that is used in the calculation of the income stream foregone
- Total profits lost due to regulation, that is, lost value of shipments times the profit/sales ratio, without discounting
- The discounted value of the profit streams, using 9.37 percent as the discount rate.

The results are given for each of three aerosol industries and for ten chemicals (CFCs and nine precursor chemicals). Estimates of quantity losses and all NPV calculations for each subsector are in separate tables.

Table VI-15 is a summary of the total profit streams foregone for all the industries. The NPV of profit streams foregone due to regulation is estimated at $789.3 million in 1976 dollars for the aerosol sector, and $248.9 million for the chemical sector, again in 1976 dollars.

OTHER INDUSTRIAL SECTORS

Other industrial sectors in the U.S. economy were directly and indirectly affected in varying degrees by the regulation of CFCs as aerosol propellants. An exhaustive list of industries affected by a regulation like the one on CFCs can, in principle, be obtained by reviewing the appropriate columns of an input-output table of the U.S. economy [65,79]. The practical difficulty in the case of CFC regulations on aerosol emissions, as noted by the National Academy of Sciences [51], is that there is neither a CFC chemical column nor an "aerosol products" column in the U.S. input-output tables. Technical economists agree that this difficulty can be overcome by "shocking" the system through the end product that was most directly affected by regulation -- in this case, cosmetics (SIC 2844). This was not done for this report because a consensus on the appropriate amount by which to shock column 2844 could not be obtained.

Thus, the presumption in this report is that there are no sectors except for aerosols (filling, valves, and containers) and chemicals in which

Table VI-15

PROFIT STREAMS FOREGONE IN AEROSOL AND CHEMICAL SECTORS, 1975 TO 1990

(Millions of 1976 Dollars)

Sector	Discounted Profit Streams Foregone Due to Regulation	
Aerosols		
Containers	104.8	
Valves	46.4	
Filling	638.1	
Subtotal		789.3
Chemicals		
CFCs	124.1	
Hydrofluoric Acid	24.9	
Carbon Tetrachloride	52.3	
Fluorspar	9.1	
Sulfuric Acid	3.6	
Sulfur	1.4	
Chlorine	25.1	
Methane	0.4	
Carbon Disulfide	5.6	
Propylene	2.4	
Subtotal		248.9
Total		1,038.2

Sources: Tables VI-2 through VI-14.

there were net quantity losses -- hence, sustained profit losses -- directly attributable to regulation. This is an important assumption.

Take the case of marketers of aerosol and nonaerosol products. By not estimating quantity losses from aerosol sales from 1975 to 1990, one is assuming that losses from aerosol sales are offset by gains from nonaerosol sales by using existing, but heretofore underutilized, capacity. Given this presumption, the approach to evaluating the economic impact of the regulations on marketers is through costs, the subject of the next chapter.

Chapter VII

ECONOMIC IMPACT ON MARKETERS

The economic impact of regulation on marketers of aerosol products is evaluated by determining the effects of regulation on their costs, both quantifiable and nonquantifiable. One type of cost is the once-and-for-all expenditure of reformulating aerosol products propelled by CFCs to alternative propellants. This cost is related to the nonquantifiable cost of R&D opportunities postponed or foregone while the firms' chemical laboratories were reformulating products. A second set of quantifiable costs were incurred by marketers who fill their own products. These costs are the initial capital expenditures of converting filling lines from handling CFCs to HCs.

This report does not hypothesize about the effects of these costs on either the profit rates of marketers or on prices paid by consumers, because there is insufficient information about the pricing policy of marketers with respect to aerosol products. As noted in the previous chapter, the presumption is also made that there is no long-run effect of regulation on the profit streams of marketers between 1975 and 1990 due to net losses in quantities sold. The quantity losses from aerosol sales are presumed to be exactly offset by quantity gains to nonaerosols.

REFORMULATION COSTS

Industry estimates that there were 65,000 aerosol products on the market in 1973; approximately 30,000 of them had to be reformulated from CFCs to alternative propellants due to regulation. Although products requiring reformulation were concentrated in certain industrial sectors, such as personal products, they range across many sectors, including: personal products, household products, veterinary products, pharmaceuticals, automotive products, spray cooking lubricants, and industrial products. A collapsed list of products containing CFCs versus other propellants in 1973, by broad categories, is in Table VII-1.

Table VII-1

THE USE OF PROPELLANTS, BY AEROSOL PRODUCT, IN 1973

	Dominant Propellant			
Aerosol Product	CFCs[a]	HCs	Compressed Gases	Combination (Blends)
Personal Products				
Antiperspirants/Deodorants:				X
Underarm Deodorants	X			
Antiperspirants	X			
Powder Antiperspirant	X			
Fragrances:				
Cologne	X			
Perfume	X			
Moisturizing Cologne Foam	X			
Bath Products:				
After Bath Spray	X			
Shaving Foams		X		
Hairsprays	X			(X)
Hairdressings	X			
Depilatories	X			
Suntan Lotion	X			
Hand Cream	X			
Skin Cleanser	X			
Food				
Food Aerosols, such as Whipped Cream[b]			X	
Spray Cooking Lubricants	X			
Pharmaceuticals and Medicines (SIC 2834)	X	?	X	
Veterinary Products (SIC 2834)	X			
Insecticides (SIC 2879)				
House and Garden	X			
Flying Insect	X			
Residual			X	

Table VII-1

(Continued)

Aerosol Product	Dominant Propellant CFCs[a]	HCs	Compressed Gases	Combination (Blends)
Household Products (SIC 2842)				
Cleaners:[c]				
Disinfectants/Deodorants	X	(X)		
Bathroom Cleaners (Detergent Type)		X		
Blackboard		X		
Oven		X		
Rug		X		
Window		X		
Upholstery Cleaners		X		
Prelaundry Spot Remover	X			
Dry Dust Mop	X			
Floor Wax	X			
Furniture Polish	X	X		
Spray Starch		X		
Air Fresheners	(X)	X	(X)	
Industrial Products				
Cutting Oils	X	X		
Design Layout	X			
Others	X		X	
Automotive Products				
Car Polish		X		
De-Icer			X	
Starting Fluid			X	
Tire inflator			X	X
Traction			X	
Undercoating			X	
Belt Drive Dressing			X	
Engine Cleaner			X	
Ignition System	X			

Table VII-1

(Continued)

Aerosol Product	Dominant Propellant CFCs[a]	HCs	Compressed Gases	Combination (Blends)
Miscellaneous				
Adhesive	X			
Animal Marking	X			
Antioxidant	X			
Artificial Snow	X	X		
Artists Fixatives	X			
Bird Repellant	X			
Dry Fly Spray (Fishing)	X			
Filters (Air Conditioning)	X	X		X
Fire Extinguisher	X		X	
Lubricant				
Oil Painting Protective Coating	X			
Photographers' Air Spray	X			
Ski Waxes	X			
Tree Wound Dressing	X			
Urethane Foam	X			
Water Repellant	X			
Paints (SIC 2851)				
Artists' Fixatives	X			
Paints		X		
Varnishes		X		

[a] CFCs include CFC-11, CFC-12, and CFC-114.

[b] Whipped cream has been the most successful food packaged in aerosol form, but Sciarra lists others that have been, or are, marketed.

[c] Almost all household cleaners are water-based, thus HCs have usually been used.

(X) = Infrequent use as a propellant.

Sources: Sciarra and Stoller [70], Commerce [76], and industry estimates.

Table VII-2 summarizes the direct labor and materials costs associated with reformulating 18,280 of the 30,000 aerosol products that had to be reformulated. It was impossible to obtain accurate information on the remaining 11,720, let alone whether it is reasonable to proportion up the costs. The direct labor costs for the 18,280 products is estimated at $168.5 million, in 1976 dollars.

The cost categories in the table show that the reformulation of these aerosol products from CFCs to alternative propellants, about 95 percent HCs, required both laboratory time and other costs. Specifically, there are five general steps in reformulating and marketing the new aerosol product. They are:

1. Chemical reformulation (lab time to convert from CFCs to HCs including any changes in solvents and active ingredients, plus preliminary packaging decisions).
2. Toxicology testing.
3. Efficacy testing -- as a product against the equivalent products of competitors and also against the previous product propelled by CFCs and distributed by the marketer. This includes in-house testing and at-home testing by 50 to 100 employees.
4. Field testing (survey of 1,000 to 5,000 people in "typical" towns).
5. Advertising.

It should be noted that these costs reflect the fact that the results of reformulation were "pooled" by industry, either through aerosol technology seminars or through journal articles. For hairsprays, resin suppliers as well as custom fillers reportedly helped customers find a workable HC-based hairspray. This had two effects: it reduced the amount of repetitive work that would otherwise have taken place in separate laboratories, and it reduced the economic burden of regulation on small marketers who -- in the absence of this help -- may not have been able to reformulate their aerosol products. In terms of reformulation costs reported in Table VII-2, this pooling of information about hairsprays reduced costs to industry and is reflected in the manhours per brand spent on chemical reformulation.

Table VII-2

DIRECT LABOR AND MATERIALS' COSTS OF REFORMULATION*

(1976 Dollars)

		Lab and R&D Time			Testing			
Product Category	No. of Products to Reformulate	Time (1000 hrs)	$ Per Hour[a]	Total Cost ($1000)	Toxicology ($1000)	Efficacy ($1000)	Field Survey ($1000)	Total Cost[d] ($1000)
Personal Products								
Hairsprays								
- Major (10 have 90% of market)	10	84	20.00	1,620	150	100	500	2,430
- Other (2,000 have 10%)	2,000	1,100	16.00	17,600	320	550	5,000	23,470
Antiperspirants								
- Major (7 have 90%)	7	175	20.00	3,300	1,350	240	350	5,440
- Other (400 have 10%)	400	800	16.00	12,800	4,000	900	3,000	20,700
Deodorants								
- Major (7 have 90%)	7	75	20.00	1,500	1,000	200	200	2,900
- Other (400 have 10%)	400	400	16.00	6,400	2,300	750	2,000	11,450
Colognes								
- Major (3 have 90%)	3	25	20.00	500	100	100	150	850
- Other (100 have 10%)	100	300	16.00	4,800	850	500	1,000	7,150
Household Products (probably 35,000 products, with about 5,000 needing reformulation)	5,000	1,000	16.50	16,500	8,500[c]	1,000	8,000	34,000
Insecticides (inside foggers and a few others were reformulated; all others already used HCs)	300	250[b]	16.50	4,130	900	250	1,500	6,780
Food								
Spray Cooking Lubricants (most done by well-known and knowledgeable contract fillers)								
- Major (3 have 90%)	3	230	20.00	4,600	200		200	5,000
- Other (50 have 10%)	50	500	16.00	8,000	200		450	8,650

Table VII-2

(Continued)

Product Category	No. of Products to Reformulate	Lab and R&D Time			Testing			Total Cost[d] ($1000)
		Time (1000 hrs)	$ Per Hour[a]	Total Cost ($1000)	Toxi-cology ($1000)	Effi-cacy ($1000)	Field Survey ($1000)	
Industrial/Institutional (probably 10,000 products - 1/3 needing reformulation)	3,300	1,100	16.50	18,200	5,200	1,300	15,000	39,700
Total	18,280	6,039		100,210	25,070	5,890	37,350	168,520

*Categories omitted from the list include automotives, "other" cosmetics, and pharmaceuticals -- about 30,000 items.

[a] This varies widely by geographic region and by the type of personnel used for reformulation. We assume an estimate of $16.00 to $20.00 per hour for a "bench chemist", in 1976 dollars. (This excludes any supervision by a senior chemist.)

[b] Includes EPA reregistrations.

[c] Mainly CPSC tests.

[d] Except advertising.

Source: Industry.

No charge for indirect costs is included in this estimate of $168.5 million. Assuming that the indirect cost is 50 percent of direct labor costs, the cost of reformulating these products was $252.8 million, in 1976 dollars. If the indirect cost is 100 percent of direct labor cost, then the cost of reformulating these products is $337 million, in 1976 dollars. Given that one is dealing with capital-intensive laboratory work, the higher figure is reasonable.

Since this information comes from a variety of sources, it is difficult to know whether costs of reformulation have been underestimated or overestimated. If one could hazard a guess, it would be that these are on the low side due to the omission of some products and the difficulty, to date, of reformulating fragrances. (This difficulty is not satisfactorily reflected in cologne cost estimates through 1980 in Table VII-2.)

Other Impacts. Almost all R&D effort by chemical laboratories of marketers and fillers for 2-1/2 to 3 years was devoted to reformulating CFC-propelled products to alternative propellants, usually HCs. This use of laboratory time means that research took a different direction from that which it would have taken in the absence of regulation. Whether it was "better" or "worse" one cannot say, but this change in the focus of R&D efforts resulted in a different array of products -- both aerosol and non-aerosol -- than would have been available in the absence of regulation. (A list of opportunities postponed or foregone due to regulation cannot be provided because it is impossible to cite cases without using proprietary information.)

In the case of industrial products, industry reports that there are products that American firms can no longer sell abroad because of the unsatisfactory nature of alternative propellants and the fact that other countries can use CFCs. Three purported cases in which U.S. producers have lost export markets are crack detectors (nondestructive testing chemicals), stencil inks (to mark drums, boxcars, and the like), and aircraft paints.

CONVERSION COSTS

A marketer-filler is a company that produces and fills its own products. The term used to describe this situation is "in-house" filling, in contrast to custom or contract filling which is discussed in Chapter VIII. Custom fillers are those who fill products for marketers on a contract basis.*

The filling operations of marketers have specific engineering costs related to converting from CFCs to HCs as propellants. As discussed in Chapter XII, there is the possibility of explosions when HCs are used. It is obviously necessary for marketers to do everything possible to prevent explosions in their in-house filling lines. No company wants accidents on their filling lines, but when the corporate names of major marketers of cosmetics are household words, the incentive to engineer away safety problems is much more compelling than it would otherwise be. Also, major marketers in the cosmetics area are more likely to have greater resources to spend on converting filling lines, because they tend to be large, diversified corporations.

A sketchy outline of the filling methods used by some major marketers of cosmetics -- before and after regulation -- is in Table VII-3. These (and other) major marketers of products are estimated to have spent \$1 to \$3 million, often virtually rebuilding their filling lines,** as part of conversion from CFCs to HCs; smaller marketers who converted spent as little as \$25,000 per line.

It is difficult to estimate a total dollar value, in 1976 dollars, of conversions of filling lines from CFCs to HCs by marketer-fillers. This requires knowing how many marketer-fillers exist and the "average price paid" for converting to HC filling facilities. A qualified total was developed as follows:

- Estimate: There were 440 filling lines owned by marketers in 1973 (this suggests marketer-fillers do about 40 to 45 percent of the filling business).

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*Although the distinction between marketer-fillers, on the one hand, and fillers, on the other, seems clear-cut, it is not. There is a grey area in which it is not clear whether someone is primarily a marketer who also fills (marketer-filler) or a filler who also markets (filler-marketer). The U.S. Bureau of the Census is confronted with this problem all the time. In reporting information, Census classifies companies on the basis of the larger proportion of value of shipments produced in one area in contrast to another.

**Estimates for many of these conversions are in annual and 10-K reports.

Table VII-3

PROBABLE FILLING METHOD BEFORE AND AFTER REGULATION*

Company	Filling Method** Before Regulation	After Regulation
Alberto-Culver Co.	In-House	Custom
American Cyanamid Co.	Custom	Custom
Elizabeth Arden	Custom	?
Armour-Dial Co.	Custom	Custom
Avon Products, Inc.	In-House and Custom	Custom
Bristol-Myers Co.	In-House and Custom	In-House and Custom
Carter-Wallace, Inc.	In-House	In-House and Custom
Chanel, Inc.	Custom	?
Chesebrough-Pond's, Inc.	In-House and Custom	In-House
Colgate-Palmolive Co.	In-House and Custom	In-House and Custom
Coty, Inc.	Custom	Custom
Helene Curtis Industries, Inc.	Custom	Custom
Faberge, Inc.	In-House and Custom	In-House and Custom
The Gillette Co.	In-House	In-House
Johnson and Johnson	Custom	Custom
Estee Lauder	Custom	Custom
Lehn and Fink Products Co.	In-House and Custom	In-House and Custom
Lever Brothers Co.	Custom	Custom
The Mennen Co.	In-House and Custom	Custom
Noxell Corp.	Custom	Custom
Plough, Inc.	Custom	In-House and Custom
Proctor and Gamble Co.	Custom	Custom
Revlon, Inc.	In-House	In-House and Custom
Norton Simon, Inc.	Custom	Custom
The J. B. Williams Co., Inc.	Custom	Custom

*The scope and choice of marketers is partially arbitrary, although the intent was to include major marketers of products propelled by CFCs prior to regulation.

**There may be errors in this table because much of it was assembled from information in annual and 10-K reports.

- Estimate: Prior to regulation, about 25 percent of these fillers had HC lines. Thus, industry estimates that the bulk of the remaining 75 percent of the 440 aerosol lines had to be converted, or 330 lines in all.
- Range of Cost Estimates: The costs of conversion varied from \$25,000 to \$3.4 million per company, and the average cost of converting a filling line was \$200,000 per line, in 1976 dollars.
- Given this, the total cost, in 1976 dollars, is \$66,000,000 (330 lines times \$200,000).
- Qualifications: Although \$66 million is presented as a point estimate of the cost of conversions, confidence intervals of plus or minus 25 percent should be attached to this estimate. It is simply too difficult to estimate a mean conversion figure for 330 lines spread among hundreds of marketers.

Chapter VIII

ECONOMIC IMPACT ON CUSTOM FILLERS

In this chapter, costs for converting aerosol filling lines from CFCs to alternative propellants are estimated for the custom filling segment of the aerosol industry. Information is also presented about the filling process and the specific safety and process modifications required for conversion by either custom fillers or marketer-fillers.

THE CUSTOM FILLING BUSINESS

The custom filling business, also referred to as packaging or contract filling, consists of operators that fill aerosol products to marketers' specifications. To stay competitive, the custom filler should be able to fill products at lower costs than the marketer doing it in-house. The lower costs are attributable to economies of scale in capital, labor, and materials.

The custom filling business has evolved over the years to provide low cost filling for the many aerosol products that have relatively small sales volumes. Of the 65,000 aerosol products on the market, many individual products have low sales volumes that are not capable of economically sustaining a filling line totally dedicated to that product's output. Custom fillers emerge to take advantage of the economies of scale present when filling several products for a number of small marketers. Many are also equipped to fill more than one propellant.

Whether the marketer or the custom filler buys the materials varies, and often depends on who can get the best price for specific products. Contracts can stipulate that the custom filler buy all the containers, solvents, propellants, valves, caps, and labels, while the marketer provides only the active ingredients or concentrate. Other contracts may, for example, stipulate that the marketer provide everything.

The savings in propellant cost when converting from CFC propellants to HC or compressed gas propellants do not accrue to the custom filler. Marketers are knowledgeable about prices of substitute propellants and can either buy their own propellant, or find another custom filler who is willing to pass the savings on to them.

The number of contract filler plants in 1980 is, by this study's estimate, approximately 213 as opposed to 250 in 1972 [39]. This study attributes the decrease of 37 plants to regulation-induced closures. The majority of these closures, 27 of 37, occurred in the smallest sector of custom filling, i.e., those with fewer than five employees; these were basement, garage, or other small operation shops.*

The percent of the total aerosol production which was filled by custom fillers after the ban is estimated to be 55 percent. Prior to the ban, Shreve estimated the percentage to be 60 [76]. While this would appear to represent a decline in custom filling business, there is too much uncertainty in the former figure to conclude that overall shifts have occurred in the shares of the market. As shown in Table VII-3 in the previous chapter, some marketers are attempting to supplement their in-house filling with custom business in order to offset their propellant conversion costs. On the other hand, other marketers have turned to custom fillers rather than make the conversions in their own filling lines. This study was unable to determine how much of this switching would have normally taken place without regulation. It seems reasonable to conclude that there has not been a significant overall change in the total custom versus in-house shares of production, but that some change has occurred in the activity of specific fillers.

This study estimates conversion costs on the basis of the number of custom filling lines times the average cost of line conversions. The estimate of the number of lines is discussed below; the cost discussion follows later in this chapter.

Estimates of the number of custom filling lines are 554 before regulation and 497 after regulation. In a 1972 survey by Johnsen [39] of 160 of the largest custom aerosol fillers, the average number of lines per plant was 2.9, for a total of 464 lines. The author also cited the existence of another 90 very small fillers (fewer than 5 employees) on which no detailed information was available. Assuming that each had only one line, and adding this number of lines to the 464 lines above gives a total of 554. As will become evident later, not all of those lines were converted to alternate propellants and not all of those that converted experienced significant costs.

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*See Chapter IX for further discussion of plant closures in the custom filling industry.

CHANGES REQUIRED BY REFORMULATIONS

As a result of the regulations on CFC aerosols, marketers reformulated their products so that they could be propelled by alternate propellants and reformulated the active ingredients to be compatible with the chosen propellant. As indicated earlier, the chosen propellant was generally HCs. Carbon dioxide (CO_2), a compressed gas propellant, was the choice for approximately 10 percent of the reformulations.

In a few instances, plant operators (both marketer-fillers and custom fillers) had their choice of alternate propellant restricted. Fillers in certain cities such as New York and Chicago are prohibited from filling with HCs. Such operators have to switch to a compressed gas, move their operations, or contract with a custom filler outside the city. A few plants are reported to have moved because insufficient space is available to them for storing the HC tank away from the occupied building. (CFC storage tanks were allowed to be stored a few feet from occupied buildings.) These instances are noteworthy; however, most reformulations occurred without such complications.

In general, the switch to HC propellants in the filling process is straightforward and involves little cost outside the costs related to safety and tank storage, which will be examined below. The change to HCs (propane, isobutane, or n-butane) essentially involves purging the gas lines and substituting the alternate propellant. A few firms that do undercap filling for aerosols have also installed reclaiming systems to avoid a concentration of HCs in the filling area that could exceed safety levels and result in automatic line shutdowns and stoppages of propellant pumping. This had not been a problem with CFCs. Losses of similar amounts of CFCs had been tolerated even though the former was more expensive.

The change to CO_2 as the substitute propellant is more involved than the change to HCs. One difference is that seals in filling heads are changed from "O" ring seals to polyurethane seals. This is required to prevent excessive amounts of CO_2 from entering the container. If more CO_2 than specified is present in the container, the excessive pressure that occurs can cause the container to explode. As a result of this risk, explosion guards are installed around machines.

Another process change sometimes required when switching from CFCs to CO_2 is a saturator or a gasser shaker, both of which facilitate propellant solubility. Also, a different quality control machine may be required. With CFCs, the performance of the filling process can be measured by weighing the can. CO_2 gas is so light that performance must be measured not by can weight but by testing the pressure of the contents. To do this, the CO_2 conversion may require the purchase of a new machine.

Generally, line speeds have not been affected by the reformulations to alternate propellants. In cases where the reformulated concentrate is more viscous and where it flows by gravity into the container, the concentrate may require heating in order to maintain previous line speeds.

The most conspicuous problem that filling operators faced in the conversion from CFCs to HCs was the increase in flammability. Chapter XII of this study discusses the inherent risk of HC propellants. This chapter discusses the engineering and other measures that filling operators have been required to undertake to reduce the risk caused by flammability.

The major organization for establishing codes dealing with the storage and piping of flammable and combustible liquids is the National Fire Protection Association (NFPA).* In addition, local fire codes and individual insurers may have different requirements. Therefore, the outline of the requirements below is not a set of specifications that each operator faced.

The NFPA codes are used by local fire departments and insurance companies as guidelines or minimum requirements. NFPA 30, "Flammable and Combustible Liquids Code 1977", is directly applicable to the storage of HCs on the property of the filler and the piping of HCs to the filling line.

HC propellants are classified as flammable (Class I) in NFPA 30. HCs can be stored in small vessels or large tanks capable of storing thousands of gallons; the latter method is prevalent. These tanks can be vertical or horizontal and must be diked in order to contain liquids if ruptures occur. The tanks are usually built on concrete pads and must be coated with silver or white paint to reduce the build-up of solar heat. Additional sublimation coatings for these tanks are also available.

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*The NFPA (as well as individual insurance companies) also establishes the requirements for aerosol container storage. See Chapter IX under warehousing.

Depending upon their size, the tanks must be 50 to 100 feet from the nearest occupied building and located away from public ways. Tanks must be a certain number of feet from each other, depending on their size. Tank loading must be performed at certain distances from the tanks. Tanks must have pressure relief valves, explosion-proof pumps and motors, and many other specified construction, installation, operation, testing, and identification features.

The CFC aerosol regulations have not changed these regulations for the safe storage and loading of HCs. However, the CFC regulations did result in conversion costs related to safety, because the normal requirements for storing nonflammable CFCs are less rigid. The most severe costs were for fillers who had no previous HC lines. These fillers had to move all storage tanks away from the building; build new foundations, piping, wiring, and fencing; purchase the land in some cases; and possibly install a fire protection system. Less cost was incurred by those fillers who were already equipped with the required tank storage farm and had only to move tanks that previously contained CFCs to locations in the required HC tank storage farm.

Under NFPA 30, piping specifications for flammable liquids cover materials of construction, supports, fittings, valve operations, coatings, and testing. Again, the CFC aerosol regulations did not affect these specifications. However, conversion costs were incurred by those fillers without such piping; they had to extend piping to the tank storage farm and place sections of pipe underground so that an explosion wall would not fall on them.

The need to create a safe "gassing house", an area in which the propellant is placed in the aerosol container, causes significant conversion costs. Again, the requirements themselves are not an effect of the CFC areosol regulations. However, they are an indirect effect in that they have to be met by those making conversions to HCs.

The process of filling containers with HC propellants must be conducted in an explosion-proof room, separate building, or in an "ear" on the building (outside room with one wall common to the building). In an inside room, one of the walls should be a blow-out wall to the outdoor area and the openings to the room for the conveyor should be minimized and equipped with special rapid closure devices. If the roof is a blow-out roof, the sprinkler system should be located on structural supports.

Within the HC filling area, several other hazard reduction features can be employed that eliminate sources of ignition, static electricity build-up, and HC vapor build-up, and suppress fires if started. Static-proof clothing can be used to eliminate static build-up. In addition, filling heads or containers can be grounded to reduce the static charge that is sometimes created during filling operations. However, even when there is apparent grounding, any change in operations must be carefully considered. For example, in one case, the static build-up on filling heads was grounded through the metal container to the filling line. However, grease was inadvertently added to the line to help line speed, causing insulation to occur between the bottom of the metal cans and the line. Static electricity built up on the filling heads and eventually created the condition for an explosion.

Special tools can be used to prevent sparks. All motors and wiring should be explosion-proofed. Obviously, no flames of any sort are allowed in such areas.

Exhaust vents are necessary to avoid increases in HC vapor concentrations. Such systems can be designed to operate at, for example, one complete room air change per minute. In the event of detected vapor build-up, the rate of air changes can be increased to three changes per minute [11]. The make-up air for normal or kicked-up changes may require heating for room heating, thus increasing cost. If the ventilation system fails for any reason, the pumping of HCs to the line should be stopped automatically.

In the event of a major HC leak, even the increased ventilation is not sufficient to eliminate the risk of explosion. Thus, explosion suppression systems must be installed in the filling room. Ironically, these systems rely on CFCs as the fire suppressant. Ultraviolet sensors in the suppression system detect when the vapor concentration has increased to about 40 percent of the lower explosive limit. At those levels, the system activates alarms, shuts off HC gas flows, and stops the filling line. The 40 percent build-up can be detected by the system whether or not the build-up is slow or part of the early stages of an explosion. An explosion is actually a slow process relative to the speed of light or sound. The flame light of an impending explosion is also detected by the ultraviolet system before the explosion actually occurs. The detection system actuates the suppression system, rupturing the spherical container of the CFCs. Several spheres may be required in a filling room. If the detection system does not work, the spheres will be activated automatically by the sound waves which also precede the actual explosion.

CONVERSION COSTS

In Chapter VII, the estimated line conversion costs for process and safety changes are presented for marketer-fillers. This section presents those costs for the custom filling segment of the industry.

An estimate of conversion costs is necessary since no organization, Federal or private, compiles records of incurred costs for all industry members. To develop the estimate, it is necessary to determine the distribution of conversions by type and estimate conversion costs by type.

Information about conversions from CFCs to other propellants was compiled from a survey of twelve firms. The survey was conducted through visits and telephone calls and also by reviewing the literature. Only nine firms were contacted to avoid the necessity for Office of Management and Budget clearance. Information on three other firms came from firms which volunteered information. The nine firms contacted were chosen at random from a list of custom fillers in Aerosol Age. It was not possible to choose them on a random, stratified basis since no size or other distributional information was available for the universe of firms. The results of this small survey were used to extrapolate costs to the custom filling industry; however, the limitations of the survey should be kept in mind when considering the total cost.

Concerning conversions to CO_2, it was estimated in Chapter VII that, of the total propellant volume that was converted from CFCs, 10 percent went to CO_2. It is assumed that this same percentage applies to custom fillers.

With regard to HCs, three of the twelve custom fillers contacted were either already using HC propellants so extensively that they encountered no incremental costs or they did not previously fill CFC-propelled products. This study uses that same 25 percent figure to derive the total number of large custom filling lines which would not incur conversion costs. (All small firms only used CFCs prior to the aerosol regulations [17].) The rest of the firms are assumed to have incurred HC conversion costs. The total number of conversions by type are shown in Table VIII-1.

The costs per conversion are determined as follows. Of the two firms contacted that converted lines to CO_2, one incurred a cost of $2,500 per line for two lines. The other firm incurred a cost of $50,000 for its one line. The average of these two admittedly divergent cases is $26,250 per line.

One of the nine firms that converted to HCs had such large costs (see Table VIII-2) that this study treats its costs separately from the costs for all other firms converting to HCs. The average cost per line is $60,312 without the one firm. However, industry representatives and consultants to the filling industry have reported that many small custom fillers did not, in their opinion, adequately engineer their plants for the HC flammability hazard when making the conversion from CFCs to HCs. Reasons given were the large size of the full conversion costs required in relation to the small financial bases of these small firms. Therefore, the estimated conversion costs of these small firms are arbitrarily assigned one-half the conversion costs of the larger firms. The effect of this assumption on total custom filler costs is not significant, as it affects the total in the extreme by plus or minus 5 percent.

Plants with deficiencies in safety measures should, in theory, be assessed higher insurance rates for the work place that would offset engineering cost savings. However, the companies contacted that had low conversion costs did not have their insurance rates increased.

The total estimated capital conversion costs for custom fillers are therefore $32.7 million, as seen in Table VIII-3. Only capital costs are reported since annual operating and maintenance costs of the conversion systems range from zero to very small.

The per line capital conversion costs for marketers (Chapter VII) was $220,000 compared to $60,312 for the larger custom fillers. The reasons why marketer conversion costs are higher than custom filling costs are that marketer lines are generally longer and some custom fillers performed their own construction-related portions of the conversions. It is also reported that custom filler firms use more inexpensive means of control than marketers, resulting in greater risks for the former, and that marketers, whose names are household words, extensively engineered away their safety problems.

Table VIII-1

TOTAL CUSTOM FILLER CONVERSIONS

	Large		Small		Total
	Plants	Lines	Plants	Lines	Lines
Number of custom filling plants and lines (1972)	160	464	90	90	554
Post-Ban Situation					
a. Shut down	10	29	27	27	56
- Lines remaining		435		63	
b. Changed to CO_2 (10% x "a" lines remaining)		44		6	50
- Lines remaining		391		57	
c. Used HCs already, therefore no costs (25% x "b" lines remaining)		98			98
- Lines remaining		293			
d. Changed to HCs					350
Small companies				57	
One large company		17			
All other large companies		276			

Sources: Pre-Ban: Johnsen, Dorland, and Dorland, The Aerosol Handbook [39].

Post-Ban: Industry representatives and telephone survey of Aerosol Age Directories.

Table VIII-2

CONVERSION COSTS FOR SELECTED CUSTOM FILLERS

Company	Plant or Company Conversion Costs	Number of Lines	Conversion Cost Per Line
1	$ 250,000	3	$ 83,333
2	75,000	2	37,500
3	150,000	3	50,000
4	60,000	1	60,000
5	13,000,000	17	764,706
6	50,000	2	25,000
7	200,000	3	66,667
8	70,000	2	35,000
9	250,000	2	125,000
Average	$ 1,567,222		$138,578
Average Without #5	$ 138,125		$ 60,312

Source: Industry.

Table VIII-3

TOTAL CUSTOM FILLER COSTS

CO_2 Conversion Costs	
50 lines times $26,250 per line	$ 1,312,500
HC Conversion Costs	
276 lines times $60,312 per line	16,646,112
57 lines times $30,000 per line	1,710,000
17 lines, one company	13,000,000
Total	$32,668,612

Chapter IX

SUPPLEMENTARY EVIDENCE ABOUT ECONOMIC IMPACT ON PRODUCERS

There are additional measures of the economic impact of regulation, but their documentation is fragmentary. Among these are:

- Capacity and capacity utilization
- Jobs lost and displaced workers
- Concentration
- Profit rates.

The extent to which one can obtain information on them varies a great deal with the industrial sector under consideration.

THE METAL AEROSOL CONTAINER INDUSTRY

A metal aerosol container is somewhat more complex to manufacture than a metal beverage container. This is largely because of higher materials costs in order to meet Department of Transportation (DOT) requirements for aerosol products and because of coating costs for cans to prevent corrosion in some aerosol products.* In 1976, the price of a "typical"** metal aerosol container was 13.5 cents.

In Chapter V, the lost quantity of aerosol containers due to regulation is estimated to be 25.8 billion cans, and the NPV of the profit streams foregone due to these lost quantities is estimated as $104.8 million, in 1976 dollars.

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*For a recent discussion of requirements for metal aerosol containers, by product category, see the article by Daniel P. Minogue, "Evaluation of Container Coatings", Aerosol Age, August 1980.

**There is, of course, no such thing as a "typical" metal aerosol container. They differ in size, which results in a price range (in 1980) from 12¢ each for a 202 x 200 can to 28¢ for a 300 x 709 can. There are also various other options that affect cost, and hence, price. Among these are the amount of lithography (the number of colors), the number of layers (and whether the side seam is striped), and whether the dome is decorated. In addition, prices vary with the size of the order -- generally declining in cents per unit for orders up to 250,000 cans and then remaining constant. Source: Industry.

Capacity. There are nine to twelve domestic companies that reportedly make metal aerosol containers.* They are: American Can (3% of which are aluminum cans), Continental Can, Crown Cork and Seal, Heekin Can, National Can, Peerless Tube Company (aluminum only), Sexton Can, Sherwin Williams, Southern Can, and Vir-jeune Can. (Some aluminum cans are also imported from Metal Box in England and Boxal in France.)

The metal aerosol container capacity of the domestic companies in 1973 has been estimated at 100 can lines, with an average capacity output per can line of about 50 million cans per year. Thus, total capacity in 1973 was about 5 billion cans a year [76, p. 60]. Since actual output required in 1973 was 2.9 billion cans,** capacity utilization was 58 percent.

Capacity in 1973 was greater than output in order for the companies to meet expected future demand for aerosols and to allow for production cycles, that is, for the fact that demand varies from month-to-month. (Certain lines might be working at maximum capacity, while others are hardly used.)

About 20 can lines that were in use in 1973 are no longer being used. (Most have been moth-balled, some have been cannibalized, and at least one was sold to a European company.) This suggests that current capacity is 80 can lines. In addition, the actual output per can line has declined because of shorter runs of a given can size; each run requires down-time between orders. Thus, line production per year is probably 40 rather than 50 million cans. This suggests that current effective capacity is 80 can lines times 40 million cans per line per year, for a total capacity of 3.2 billion metal aerosol containers per year.

Investment. Potential overcapacity in the metal aerosol container industry was exacerbated by the fact that new metal aerosol container lines came onstream; they had been planned and construction had begun prior to the announcement of the ozone depletion hypothesis in June 1974, an hypothesis which was totally unanticipated by industry. The planning period for a decision to introduce new aerosol container plants or new lines is two to three years. In addition to expansion, a modernization drive (to welded technology) was underway. At least four plants came on line after June 1974, namely, Southern Can (1 plant), Continental Can (2 plants), and American Can (1 plant). Assuming each plant has three lines, the estimated investment in these four plants is \$6 to \$8 million per plant, or \$24 to \$32 million in 1976 dollars for the industry.*

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*Sources: CSMA data on reporting companies and industry estimates.

**Although Can Manufacturers Institute (CMI) and Census numbers showing cans shipped exist, can shipments based on units filled (CSMA data) are used in order to conform to other parts of the report.

Employment. The effects of the reduction in capacity on employment can be quantified on the basis of the information about industry capacity in 1973 and 1980, supplemented with other information about the number of workers required per line.

In general, industry estimates that the average can line requires 62 people, including both production workers and overhead labor. In the case of production workers, each line requires 20 to 40 people (3 people on the presses, 3 lithographers, 2 in the body-making area, and the rest throughout the line). The overhead labor includes inventory control, purchasing of materials, selling of cans, quality control, accounting, personnel management, and general management. Total employment can be seen in Table IX-1. The losses due to regulation can be calculated using these pieces of information.

Table IX-1

LOST EMPLOYMENT IN THE AEROSOL CONTAINER INDUSTRY

Year	Can Lines	Total Employment
1973	100	6,200[a]
1979	80	4,960
Employment Loss, 1979 vs. 1973		1,240

[a] This is close to the Commerce estimate of 6,000 workers in 1974 [76].

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*Container industry estimates.

It is impossible to document what happened to the estimated 1,240 workers who lost jobs in the metal aerosol container industry due to regulation. It can be assumed that some were retired. Some of the adjustments were relatively smooth for employees, with retirees simply not being replaced. There are, however, cases in which workers were unable to find jobs elsewhere at the same skill level and salary scale. The typical case cited on the production line is that of the lithographer, whose wages plus benefits are as high as auto workers; however, lithography is a nontransferrable skill. With regard to overhead labor, details of their reemployment cannot be quantified.

Concentration. No information is available on changes in the relative shares of the market by various metal aerosol container manufacturers. One small company, Shield Chemical Company, may have left the container market, but no documentation of this was uncovered.

Impact on Profit Rates. The following seem to be true about the impact on costs and profit margins for the metal aerosol container market as a whole:

- Metal aerosol container manufacturers were able to pass on all increases that were due to the inflation of the Seventies, including costs of materials (and much rising of labor costs). Since metal (and plastic) containers are energy-intensive industries, this is a significant pass-through of costs.
- Metal aerosol container manufacturers were unable to pass along the effects of underutilization of capacity on costs, these costs being partly overhead labor costs and partly the result of down-time for smaller orders for each sale. These costs also appear to be significant.

Stated differently, one could "explain" the difference between the 1976 price of 13.5 cents for an aerosol container and the 1980 price of 20 to 25 cents per container merely by looking at increases in (a) the price of energy used to produce metal, and (b) the wages of production workers. By definition, profit margins have fallen because of increased costs per unit of overhead labor and increased costs of down-time for smaller orders, both a result of regulation. Due to the current competitive situation, container manufacturers have not been able to pass on either of these costs in the form of higher prices.

THE GLASS AEROSOL CONTAINER INDUSTRY

Glass aerosol containers are primarily used in the cologne and pharmaceutical industries. In the past, the bulk of industry shipments were for colognes. For example, of the estimated 130 million glass aerosol containers made in 1973, 85 percent were used by the fragrance industry, with the remainder being used by pharmaceutical manufacturers.*

Since regulation, there have been drastic changes in both the total quantity of glass aerosol containers shipped and in the distribution between fragrances, on the one hand, and pharmaceuticals, on the other. The total quantity of glass aerosol containers shipped in 1979 was 32 million, or 25 percent of the 1973 market size. The change in the distribution between pharmaceuticals and colognes is equally dramatic. From a high of 90 percent in 1972, the fragrance market reached an apparent trough of about 30 percent of the glass aerosol container market in 1977. Table IX-2 summarizes the results by year, 1970 to 1979.

Thus, the economic impact of regulation on the glass aerosol container industry is inextricably bound up with the economic impact of regulation on the fragrance industry. As discussed earlier, fragrances have proven to be one of the most difficult products for marketers to reformulate from CFCs to alternative propellants.

A glass aerosol container is a much more labor-intensive product than a metal aerosol container. This is particularly true for coated bottles, that is, glass aerosol containers with a fine plastic film on the outside.**

In 1976, for example, when a typical metal aerosol container sold for 13.5 cents, industry estimates that a typical glass aerosol container sold

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*Source: CSMA [17].

**The coating reduces hazards from breaking glass, including the possibility of the regulation-induced propellant, HCs, igniting in the presence of flames. The surcharge for coating is considered by industry to be a cost of regulation.

Table IX-2

GLASS CONTAINERS (COATED AND UNCOATED) USED TO FILL PRESSURIZED PRODUCTS: 1970 TO 1979

(In Thousands)

Year	Pharmaceutical (OTC and Ethical)	Colognes and Fragrances (Except After Shave)	Fragrances as % of Total[a]
1970	7,858	74,191	90.4
1971	14,451	73,828	83.6
1972	11,139	100,101	90.0
1973	19,772	110,330	84.9
1974	NA	81,689	NA
1975	10,511	43,943	81.4
1976	NA	28,420	NA
1977	10,030	4,234	29.8
1978	11,408	8,141	41.7
1979	9,856	22,471	70.2

[a] Total is defined as sum of fragrances and pharmaceuticals. Excluded are some other personal product categories, because they are not reported by product.

NA = Not Available.

Source: CSMA, "Pressurized Product Survey" [17]. Annual Issues.

for 17 cents. (For colognes and some pharmaceuticals, the extra cost of glass is acceptable because of the aesthetic benefits and the fact that the glass is chemically neutral in the presence of the active ingredients.)

Industry sources estimate there are only four firms that manufacture glass aerosol containers. They are reportedly Brockway, Carr-Lowry, Owens-Illinois, and Wheaton Plastic-Cote. One of these companies is estimated to have between 70 and 90 percent of the market; market share has reportedly not changed since regulation.

Economic Impact. Industry sources agree that the only thing that has kept glass aerosol container manufacturers in business at all in the past few years has been those pharmaceuticals that are still propelled by CFCs because they are essential-use exemptions. This is because fragrances were one of the most difficult product groups to reformulate and also one that required a coated glass aerosol container to reduce hazards due to the flammability of HCs.

The NPV of profit streams foregone in the container industry is underestimated in Chapter V because the price of metal aerosol containers is used in the profits calculations, instead of a weighted average of metal and glass aerosol containers. Yet glass containers command a higher price than metal containers. An adjustment in the NPV calculations for containers could be made for 1975 through 1979 because estimates of demand in the absence of regulation and demand with regulation are available for colognes. But lost quantities beyond 1979 cannot be forecast, because a macroeconomic approach to estimating demand between 1980 and 1990 on has been taken. This underestimate of profits foregone is thus noted, rather than quantified.

The glass aerosol container industry is relatively optimistic about the future for two reasons:

- Fifteen to twenty companies have now reformulated their fragrances so that the products can be propelled by HCs, or CFC-152a
- The coated bottle technology is regaining acceptance as the appropriate, safe package for aerosol colognes.

THE VALVE INDUSTRY

An aerosol valve is a summary term for a product with six to ten different (largely plastic) components. The purpose of the aerosol valve is to enable the propellant to deliver the active ingredients safely to the consumer with the appropriate spray characteristics.

Valves are, to some extent, a differentiated product. That is, unlike metal aerosol containers where all 202 x 212s are much the same, valves are not. The valve "package" differs depending on the aerosol products and the propellants and -- to some extent -- among companies.

The use of HCs has resulted in some changes in the standard valve package in the personal products area. One change involves the vapor tap valve* for hairsprays and antiperspirants. It is able to lower the delivery rate of the product and produce a finer dispersion of the HC propellant. This results in a less flammable but coarser spray than the standard valve. The other change involves the use of techniques to decrease the size of the orifice in the standard valve in order to produce a finer spray. The standard dip tube has also been replaced by a capillary dip tube.

The price of a "standard" valve (and cap) was about 5 cents a piece in 1976. Although vapor tap valves cost slightly more than standard valves, industry estimates that the surcharge is insignificant (about $1 for a thousand valves).**

The quantities of valves not produced due to regulation are estimated in Chapter V to be 25.8 billion. The NPV of the profit streams foregone due to these lost quantities was estimated to be $46.4 million, in 1976 dollars.

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*The vapor tap type valve has been used since the mid-Fifties. What has changed due to regulation is its relative share of the market. New capacity was required to produce the additional demand for these valves due to regulation.

**The price of other special valves can add 1¢ a can ($10 per thousand). "Special" valves include those with an expensive button, a Viton gasket, a stainless steel cup, special spouts, or overcap actuators up to 3 inches in diameter. (One company makes a manually pretested meter spray valve that sells for 18.5¢ a piece.) Thus, there is a wide spread in prices. It is impossible to sort out whether any of this is due to regulation, so the assumption is that it is not. Source: Industry.

Capacity. There are about nine or ten companies that make aerosol valves. Those who reported their quantity of shipments in 1979 to CSMA* are: Clayton, Cope Allman Valves, Ethyl Products, Precision Valve, Riker Laboratories, Risdon, Seaquist, Spray Products, and Summit Packaging. Newman-Green also reportedly manufactures aerosol valves; Clayton is largely a manufacturer of food valves.

The capacity of the aerosol valve industry has been estimated at about 5 billion valves per year both in 1973 and 1979. Capacity utilization -- although only 48 percent in 1979 -- was just 58 percent in 1973.

There have been substantial shifts within the industry, with at least one firm (Precision) withdrawing capacity. Others have added to their capacity, sometimes through new investment, but in one case, through the acquisition of existing but largely unused lines.

Investment. It is always difficult to establish the amount of investment that would have occurred in the absence of regulation from that which did occur with regulation. The valve industry is no exception. An educated guess is that at least $2 million, in 1976 dollars, was spent on research by valve manufacturers into possible types and combinations of valve parts as a result of the change from CFCs to HCs.** Each of the two largest valve manufacturers are estimated to have spent four years researching the problems related to changes in propellants induced by regulation. The investment in R&D per company is estimated to be $408,000 (10 people per year for 4 years at $20.00 an hour for 2,040 hours per person per year). A low estimate of time spent on R&D by other companies in the industry is that each of the 5 to 7 companies spent one-half of the budget of a major supplier ($204,000 times 5 to 7 companies equals another $1.02 to $1.43 million). The total investment made by the valve industry is therefore $1.84 to $2.25 million.

Plastic molds required to manufacture the new valves are estimated to cost about $100,000 each.*** Assuming each of the two largest manufacturers had 20 new molds made, the investment is $4,000,000. No information is available on the investments in new molds by other firms in the industry.

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*CSMA, "Pressurized Product Survey," 1979 [17].

**Source: Industry estimates.

***Source: Industry estimates.

Jobs Lost. The U.S. Department of Commerce [76] estimated employment in the valve industry at 2,900 people in 1974. Each of these workers produced an estimated 100,000 valves per year (2.9 billion units filled in 1973/2,900 people). At least half of the production workers in valves are in quality control.

Industry estimates that more workers have become unemployed due to regulation than the quantity drops would imply. This is because the investment in new, ban-related equipment has resulted in a tripling of output per manhour to about 300,000 valves per year. There is no information on the reemployment of these people.

Concentration. There has been a shift in market shares. The market share of the largest company (Precision Valve) has been reduced; however, this reduction in market share is said to be unrelated to regulation.

There have been plant closures (one by Precision Valve and one by Ethyl Corporation), and Risdon is reported to have gone out of the aerosol valve market. These closures are attributable to quantity losses associated with regulation.

Impact on Profit Rates. The following information seems to be true about the impact on costs and profit margins within the valve industry:

- Aerosol valve and cap manufacturers were at most able to pass on the increases in their costs of materials and wage rates -- increases that were due to the inflation of the Seventies. Since plastic is an energy-intensive industry, this caused a significant rise in prices due to inflation.*
- Aerosol valve and cap manufacturers have been unable to pass along the higher costs of lower capacity utilization (higher overhead labor costs and more down-time as a result of smaller orders) and also of R&D and of investment due to regulation, both as a result of regulation.

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*The situation in valves is more difficult to document than in the case of metal aerosol containers because BLS does not have a long enough historical time series for various plastic products. The fact of the energy-intensiveness of the industry, of course, can be documented.

The result of this has been a squeeze on profit margins, even before the recession of 1980. This profit squeeze is due to regulation in the sense that (a) output is less than it would have been in the absence of regulation, so there is overcapacity in the industry and fierce price competition among firms within the valve market, and (b) some investment has had to be made in order to meet valve needs for HCs, where HCs have different features than CFCs. These investment costs are being paid back at a slower rate than expected due to increased market competition as a result of reduced demand for aerosols because of regulation.

THE CFC PROPELLANT INDUSTRY

CFCs are organic chemical compounds consisting of chlorine, fluorine, carbon, and (sometimes) hydrogen. They were used in aerosol products because of their low flammability, chemical stability, low toxicity, solubility, inertness, and a variety of other properties that aid formulation of aerosol products (such as solubility and vapor pressure characteristics). Stated differently, CFC propellants do not interfere or react with the active ingredients in aerosol products; they reduce or eliminate flammability hazards of other formulation components; and they readily supply the range of spray characteristics desired. Their high density is also helpful in suspending emulsions. Offsetting these advantages prior to 1974 was the high cost of CFCs relative to HCs, the chief alternative propellant.*

Thus, prior to 1974, CFCs were primarily used in products in which their fire retardant property or their inertness was viewed as of critical importance, whereas HCs were the chief propellant in aqueous-based products in which flame suppressant features were less important. CFCs were the primary propellant in spray cooking lubricants, pharmaceutical products, some industrial products, and in most alcohol-based personal products (hairsprays, antiperspirants, deodorants, and colognes). HCs were used in water-based aerosol products such as shaving lathers, window cleaners, spray starches, room deodorants, and space insecticides. HCs were also used in alkali solutions, such as oven cleaners, where their stability in such solutions was important.

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*The disadvantage of CFCs relative to alternative propellants is, of course, also the environmental concern raised by the ozone depletion hypothesis. CFCs released at the earth's surface are very stable. Since they are stable, CFCs have a long life in the atmosphere, which permits them to mix up into the stratosphere over a ten- to twenty-year period. At high altitudes, CFCs are broken down by radiation, and the constituent chlorine is released. Chlorine goes through a chemical cycle summarized in two relationships: (1) $Cl + O_3 \longrightarrow ClO + O_2$ and (2) $ClO + O \longrightarrow Cl + O_2$. The extent to which this describes what actually happens as an overall process in the stratosphere is still a matter of debate.

A small number of aerosol products (5 to 10%) are propelled by compressed gases in contrast to CFCs or HCs. Compressed gases have a major advantage over other propellants in low-temperature situations and are also nonflammable and inexpensive. The present difficulty with wider use of compressed gases as propellants is that they produce a coarse and uneven spray. As a result, compressed gases are chiefly used in automotive products (including windshield de-icers and tire traction sprays) and some industrial products.

In Chapter V, it is estimated that between 1975 and 1990 CFC manufacturers sold 8.8 billion fewer pounds of CFCs as aerosol propellants than they would have in the absence of regulation, and that the NPV of that profit stream foregone was $124.1 million, in 1976 dollars. These results must be qualified, however, because unlike the case of the aerosol sector, industry advises that CFC capital equipment has an economic life beyond 1990. This being the case, the quantity losses (and profits foregone) also extend beyond 1990. The amount of the impact depends on a more reasonable estimate of the remaining life of the equipment.

Background Information. CFC-11 (trichlorofluoromethane, or CCl_3F) and CFC-12 (dichlorodifluoromethane, or CCl_2F_2) were the primary CFCs used as aerosol propellants; CFC-114 was used to a lesser extent. The average price paid for CFC-11 in 1976 was 34 cents per pound and the average price paid for CFC-12 was 41 cents per pound.* (CFC-11 is cheaper than CFC-12 because it contains more chlorine and less fluorine.)

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*Source: U.S. International Trade Commission [95]. There are no published price and quantity data for CFC-114. For the purposes of much of the economic impact assessment in this report, the total aerosol output is divided into exhaustive categories, that is, the sum of CFC-11 + CFC-12.

Capacity. In 1979, there were four firms producing CFCs for the aerosol market: Allied, DuPont, Kaiser, and Pennwalt. In 1974, there were six: Allied, DuPont, Kaiser, Pennwalt, Racon, and Union Carbide. (Union Carbide no longer manufactures any CFCs, whereas Racon reportedly no longer sells CFCs intended for aerosol use.)

The production of CFCs as aerosol propellants dropped from a peak of about 520 million pounds per year in 1973 to an estimated 21 million pounds per year in 1979. (The 21 million pounds per year is due to essential-use exemptions to the ban.) Total production (aerosol and nonaerosol) of CFC-11 and CFC-12, the principal aerosol propellants, is not expected to regain 1976 levels until at least 1990 with present projected technology and uses [Wolf, 99, p. 2].

A result of the sharp decline in aerosol use has been the closing of plants by Allied, DuPont, and Pennwalt and the exit of Union Carbide from the industry. For CFC-11, CFC-12, and CFC-114, 1977 nameplate capacity with closures has been estimated at 715 million pounds [Wolf, 99, p. 29]. The capacity of the plants that were closed due to regulation is estimated to be 435 million pounds per year; this uses information about which plants closed and data in the IR&T report [36, p. 2-21].

It is more difficult to assess the situation in 1980. Some industry sources suggest that CFC-11 and CFC-12 plants are, on average, at a "trigger rate" for further closings, depending on the outcome of Phase 2.*

Jobs Lost. The employment effects of regulation on the CFC industry are discussed in Chapter X of this report. It concludes that 2,000 jobs were lost in CFC production. Some of the CFC producers report that workers that were laid off were offered employment elsewhere in the corporation. Sometimes this involved geographic relocation, though it is unknown to what extent offers of relocation were accepted. Thus, there is no information on what happened to these people in terms of reemployment or in terms of the salaries they were paid elsewhere. As explained elsewhere in this report, the reasonable assumption is that labor found employment elsewhere, unlike the capital equipment in CFC production that became unusable.

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*The announcement of the Intent to Regulate nonaerosol uses of CFCs, October 7, 1980.

Impact on Profit Rates. There is scattered, qualitative information on what happened to profit rates. Profit rates (for example, profits on sales) are said to have declined dramatically between 1974 and 1976 to 1977. At that point, plants were closed, and the profit rate on the existing plants* rose, although probably not to its preregulation level.

PRECURSOR CHEMICAL INDUSTRIES

In Chapter V, estimates of the billions of pounds of each of nine precursor chemicals lost due to regulation are reported. The NPV of the profit streams foregone for those nine precursor chemicals was estimated to be $124.8 million, 1975 to 1990, in millions of 1976 dollars.

Plant closures were a significant additional impact of regulation on the industries, although it is difficult to identify all of the plants that have closed for the nine precursor chemicals due to regulation. Industry reports that two CCl_4 plants have shut down -- one by Stauffer and one by FMC. Three HF plants (Allied, DuPont, and Kaiser) were closed in the last three years.

Those with further interest in the economic impact of aerosol regulation on precursor chemicals should read Wolf [99].

CUSTOM FILLERS

It is estimated that 25.8 billion units of aerosols were not filled that would have been filled in the absence of regulation. The NPV of profit streams foregone due to the lost quantities is estimated to be $638.1 million in 1976 dollars. In addition to profits lost due to lost quantities, there were initial capital costs of converting filling lines from CFCs to alternative propellants, where the estimated total cost is $32.7 million by custom fillers.

Plant Closures. The closure of approximately 37 custom filling plants, representing 56 filling lines, can be associated with the CFC aerosol regulations. Approximately 30 percent of the 90 small custom fillers have closed. However, the plant closures do not appear to be relegated to small custom fillers. There have been at least nine large custom filler plant closures, including Capital Packing Company, one of the largest custom fillers in existence, which closed three plants, and Barr, which closed a large plant in Baltimore. It has also been rumored that a very large Southern custom filler is negotiating with other custom fillers for the purchase of its business. Since the review of the large plant closures was not exhaustive, ten has been used as a reasonable estimate.

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*For a critique of the profit rate criterion, see Appendix C.

The closure decisions appear to involve plants which were not very profitable to begin with and which were faced with large capital outlays for converting to HC filling. However, the number that would have gone out of business anyway is unclear because there is no historical data to use for a comparison.

Jobs Lost. The employment impact for custom filling is estimated by multiplying the lost business, represented by diminished demand, by the employee-to-filling-units ratio. The seven custom fillers contacted have an average employee to million-units-filled ratio of 4.44.

The range of the ratios for the firms was considerable -- 0.3 to 12.7. Some custom filling operations are very large and rank with the sizes of marketer-filler operations. Some of these lines are automated to a great degree with machines such as automatic unscramblers and packing equipment. Other lines are more labor-intensive, hence such a large range in employee-to-filling ratios.

The number of average annual filling units lost in aerosol filling between 1973 and 1979 amounted to 0.6 billion. Of this, 60 percent or 0.36 billion would have been handled by custom fillers. At a 4.4 person ratio per million units per year, the diminished demand amounts to a decrease in jobs in the custom filling industry of 1,584. It is not known to what extent the displaced workers found reemployment. Unlike the case of CFC/aerosol capital, however, it is reasonable to assume the displaced workers were reemployed in nonaerosol filling lines within the same firm or found alternative employment elsewhere, given their skill mix.

WAREHOUSING

The insurance industry is not only concerned with risks associated with producing aerosols, it is also devoting considerable attention to requirements for storing aerosol containers at all points in their distribution, from the manufacturer/packer to the final point of sale. In particular, the focus is on warehouse storage.

The current standard in the industry for storage practices and fire protection systems when aerosols are being warehoused is Factory Mutual's Data Sheet 7-55. However, because of large fires such as the Pathmark fire in January 1979 or an earlier Boston fire which involved aerosols, Factory Mutual is expected to revise Data Sheet 7-55, and other insurance companies are expected to follow.

The new standard will be based on recent tests (discussed in Chapter XII of this report), and will be divided into three categories based on the active ingredients, regardless of propellant. The categories are water-based, water-soluble, and flammable-nonsoluble. The present storage requirements of Factory Mutual's Data Sheet 7-55 are deemed satisfactory for the water-based products. For the water-soluble category, the storage requirements will be increased over those presently required by Data Sheet 7-55; they will include sprinkler systems at every five-foot level (instead of just ceiling sprinklers) for multiple tier storage, and cyclone or cage fencing around the perimeter of the area in which aerosol containers are stored. If three or more racks of aerosol containers are stored, then face sprinkler systems will also be required.

For the flammable-nonsoluble category, the storage requirements for water-soluble products will apply, with the additional requirement of a sprinkler system capable of delivering twice the rate of water that is presently required.

The required delivery rate of sprinkler water is presently 0.3 gallons of water per minute per square foot of floor area. This rate must prevail at the point in the overhead water distribution system with the lowest water pressure. Each 1/2-inch orifice in the system typically delivers 30 gallons per minute. If 17/32-inch orifices were installed, the delivery rate of the sprinklers could be doubled.

Impacts on Cost. The cost to simply increase the delivery rate of the sprinklers from 0.3 to 0.6 gallons per square foot of floor area is significant. Many public water systems are not pressurized enough to deliver 0.6 gallons per square foot under normal conditions. The cost of a pump and storage tank to increase the pressure from 0.3 to 0.6 might be $250,000 plus the cost of a backup pump. For general warehouses, which normally run at low profit margins and are not equipped to handle other hazardous materials, this cost is extremely burdensome, according to information that Factory Mutual representatives have received from warehouse clients. A Factory Mutual representative suggested that the cost increment in going from 0.3 to 0.6 ceiling density is equal to the initial costs for attaining 0.3.

Other explosion or flame suppressant systems with ultraviolet sensors are cited by the Factory Mutual Standards Group as being even more expensive. In addition, these systems alone are not reliable enough to be used to control fires in warehouses.

The present implementation of these upgraded requirements by Factory Mutual and at least one other insurer is causing considerable reaction from the warehousing industry. Many warehouse operators faced with these requirements are now asking the aerosol product manufacturers for information about the makeup of the active ingredients of the stored products. The warehouse operators can either refuse to carry the aerosol products they are not equipped to store or install the storage and sprinkler systems. If the former choice is made, aerosol product manufacturers will have to either distribute the products directly to each retail outlet or find an equipped warehouse. Both of these alternatives involve increased costs.

The warehouses which will be affected the most are the food warehouses servicing chain stores. These warehouses do not separate pallets which are to be stored and they do not have rooms or fenced areas where they could be segregated. Some public warehouses, on the other hand, are already equipped for the new requirements because such requirements have applied to other products for several years. Those operators are accustomed to special treatment of products.

Whether or not these impacts should be attributed to CFC regulations is currently controversial. Factory Mutual does not believe that their new requirements are related to the CFC regulations because the Factory Mutual categories are based on active ingredients, not propellants. Others disagree, pointing out that Factory Mutual's evaluation was made without considering a major product in terms of sales (antiperspirants) which is more than 35 percent propellants. A change of that amount of propellant to a flammable propellant, it is felt, should be seen as adding significantly to the overall hazard of aerosols and therefore to the need for more stringent fire protection guidelines. In addition, it is argued that Factory Mutual did not compare the same active ingredients propelled by CFCs with alternative propellants. For that reason, Factory Mutual would not be able to evaluate the relative contributions to warehouse fires of aerosols propelled by CFCs, on the one hand, and HCs, on the other.

Because this controversy has not been resolved, the cost and other impacts on warehousing have not been quantified and have not been included in calculations of the total economic impact of regulation.

Chapter X

ECONOMIC IMPACT ON EMPLOYMENT

Labor as well as capital was affected by changes in demand attributable to CFC regulation. Without regulation, there would have been a certain number of jobs requiring various skills distributed among the relevant industrial sectors. With regulation, there are fewer jobs in these sectors due to lost output. The difference between the two situations can be calculated, at least in principle, as the NPV of the "employment effect" of regulation -- measured in millions of dollars of salaries lost to workers and discounted to 1976.

However, calculating the NPV of salaries lost due to regulation is less plausible than calculating the NPV of profit streams foregone due to regulation because of the nature of the labor inputs in contrast to capital inputs. In the case of capital, comparisons of the present value of profits with and without CFC regulation can be made because of three legitimate assumptions: (a) capital equipment was unemployed due to regulation; (b) it was dedicated to aerosol or to specific chemical production; and (c) it had a remaining economic life of at least 15 to 20 years.

The impact of a regulation on labor usually differs, however, from its impact on capital. Although a certain number of job positions may be lost due to regulation, just as machines are idled, the displaced workers can generally find alternative employment elsewhere in the economy. Thus, the effects of a regulation on labor are likely to be small.

The assumptions that are generally made about the employment effects of labor idled due to a regulation are:

- Some jobs are lost due to regulation, but
- Most workers are reemployed elsewhere in the economy (as opposed to being permanently withdrawn from the labor force). Of these displaced workers, some are reemployed within the same firm in similar jobs and do not incur any costs; others have to move, either geographically or from one employer to another and, in the process, may bear costs of transition. A few may be forced to accept jobs at a lower wage than in the absence of regulation.

The primary objective of this chapter is to estimate the number of jobs lost due to regulation in the chemical and aerosol sectors between 1973 and 1979. A secondary purpose is to present the scattered evidence that is available on the reemployment of these workers whose job positions were lost due to regulation.

The Baseline Case (Preregulation)

In order to estimate the number of job positions lost due to regulation, information on preregulation employment in the affected sectors is required. The Shreve data in the Commerce report [76] are the best set of baseline data available on employment in the aerosol sectors. Salient parts of the Commerce table are reproduced in Table X-1. The 1973 preregulation level of jobs in the aerosol sector is estimated at 32,600, obtained by including employment in all sectors except marketers and concentrate suppliers.

For the chemical sector, it is more appropriate to use IMOS figures [21] and industry estimates. The pre-regulation estimate of jobs in CFC production is 4,000 people. Since about half of CFC production was for aerosol use in 1974, approximately 2,000 people were employed by CFC producers to make CFCs for aerosol use. For precursor chemicals, the baseline estimate is 4,500 jobs.

Proportionality Between Jobs and Output

An assumption of proportionality between labor inputs and product output is the reasonable assumption to make for comparing the preregulation situation (1973) with 1979. This is true because industry has had time to adjust overhead labor as well as production labor to diminished output due to regulation. Although one recognizes there are always lags in laying off workers due to temporary declines in output (most typically, due to the business cycle), the aerosol industry seems to have reduced employees at all levels in response to its longer-run view of the industry as "depressed" due to regulation. Although the evidence about proportionality is less complete for the chemical sector due to the impossibility of tracing employment effects through nine precursor chemicals individually, scattered evidence

Table X-1

EMPLOYMENT AND PAYROLLS IN AEROSOL SECTOR, 1974

Industrial Sector	Employment (Equivalent Full-Time Position)	Payrolls or Salaries (Millions)
Aerosol Products		
Marketers	9,000	$ 81.2
Filler-Marketers	10,500	101.0
Contract Fillers	8,600	55.3
Total	28,100	$237.5
Containers	6,000	66.7
Valves	2,900	21.1
Concentrate	10,400	100.3
Other Raw Materials	1,900	27.8
Shipping Carton Mfg.	1,500	15.7
Cap Mfg.	1,200	9.3
Total	52,000	$478.4

Source: "The Economic Magnitude of the Aerosol Industry," R. R. Shreve, Northern Illinois University, DeKalb, Illinois, 1975, as reported in the Commerce report [76].

suggests the presumption of a proportional relationship between labor inputs and product output is also appropriate in that case.

Job Positions Lost

The number of jobs lost due to regulation can be estimated using pre-regulation data on employment, 1973 and 1979 data on output, and an assumption of proportionality between jobs and output. The arithmetic can be illustrated for the aerosol sector. In 1973, 32,600 people (excluding marketers and concentrate manufacturers) were required to produce 2.9 billion units of aerosols. In 1979, the output of aerosols was 2.407 billion units. This implies a labor force of 27,058 and thus a reduction of 5,542 job positions in the aerosol sector for 1979 compared with 1973.

Estimates for the chemical sector are somewhat simpler because output for aerosol use dropped from more than 500 million pounds per year to almost zero. In 1973, it was estimated that CFC producers employed 4,000 people. Since about half of CFC production in that year was used for aerosols, and output in that sector is now close to zero, approximately 2,000 job positions were lost due to regulation. For precursor chemicals (summed), the baseline estimate of employment in 1974 was 4,500. Scattered evidence suggests that approximately 25 percent of precursor chemicals were affected by CFC regulations, suggesting that 1,125 jobs were lost in the precursor chemical sector. For chemicals (CFCs and precursors), the total estimate of job positions lost is thus 3,125 (2,000 plus 1,125).

For both the chemical and aerosol sectors, 8,667 jobs were lost due to regulation (5,542 plus 3,125).

Reemployment

It is impossible to quantify the number of displaced workers that found reemployment elsewhere in the economy without undertaking a task of major proportions involving a great deal of field work.

The scattered evidence available suggests that the majority of workers were reemployed elsewhere. In general, the chemical sector has large diversified firms whose growth in other markets would allow for absorption of affected workers. Some of the CFC manufacturers that closed plants offered the affected workers jobs elsewhere in the companies.

This does not deny that there are human interest stories of careers interrupted by the regulation. However, it is reasonable to assume that most displaced workers found alternative employment.

No attempt was made to estimate the number of new jobs created by increased demand for the nonaerosol substitute products. The following, however, seems to be true based on scattered evidence from industry. Nonaerosol filling is estimated by industry to be 20 percent more labor-intensive than aerosol filling. Nonaerosol containers, chiefly plastic, however, are half as labor-intensive as aerosol metal containers to produce, chiefly because of the fact that there is no need for lithography or separable tops on plastic containers. Manufacturing the typical mechanical pump and aerosol valve is said to be equally labor-intensive, but the existence of some special aerosol valves with overcaps may result in a greater use of labor per unit of output in aerosol valve manufacturing.

Chapter XI

EVALUATION OF THE EFFECTIVENESS OF LABELING REQUIREMENTS

One objective of this study is to evaluate the effectiveness of the labeling requirements for products containing CFC propellants. The intent of the requirements was to cause a change in consumer purchasing patterns by distinguishing those aerosol products that contained CFCs from those that did not. The requirements were proposed in 1976 and 1977 by two Federal agencies: FDA and CPSC. FDA announced its final requirement in April 1977; this regulation covered about 80 percent of all products containing CFCs as aerosol propellants.* CPSC announced its final labeling requirements in August 1977 for the estimated 13 percent of household products that contained CFCs as aerosol propellants at that time.

This study finds that it is impossible to reach firm conclusions about the effectiveness of the labeling requirement, largely because both the labeling requirements and the proposed ban were announced in the same year, 1977.** Even the qualitative evidence is somewhat mixed. However, the following observations can be made:

- After the announcement of the ozone depletion hypothesis and prior to labeling requirements, articles in newspapers from across the country already distinguished between those aerosols that were likely to contain CFCs and those that probably did not. The following statement is fairly typical:

  > "Generally, the cans that do contain fluorocarbons are in the health and beauty aids category: deodorants, hairsprays, and fragrances. Those that do not are generally household cleaners, spray paints, food toppings, and shaving lathers."

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*Cosmetics, pharmaceuticals, and food products are under FDA jurisdiction. These three product areas were, as this study has noted, among the most CFC-dependent sections of the aerosol industry.

**The final labeling requirement by FDA was announced on April 29, 1977, and the proposed ban was issued on May 13, 1977. On August 24, 1977, CPSC announced its final labeling requirement.

Thus, the media were performing the role of informing consumers about propellants, and thereby accomplishing some of the objectives of the labeling requirement.

- After the labeling requirements, there seems to have been a decrease in the amount of newspaper coverage devoted to identifying products by propellant, presumably because the role of identifying propellants to consumers was being achieved by the labeling requirement.
- Prior to the labeling requirement, a CPSC study* of 1,800 people in 37 states resulted in two findings:
  - Forty percent of the people polled said they had voluntarily cut back on aerosol sprays because of environmental concerns, but
  - Most did not know which product contained what propellant.
- When the labeling requirements were announced in 1977, demand for all aerosol products dropped relative to demand in 1976. This further "nosedive" in aerosol demand was often independent of the propellant, as shown in Table V-2. If nonCFC-propelled aerosol demand had not also dropped, a case could be made that the labeling requirement was effective.
- Some marketers believe that labeling helps, since they now voluntarily label aerosol products with statements such as these:
  - "Contains No Fluorocarbons."
  - "Does Not Contain Chlorofluorocarbons."
  - "Environmentally Safe. Contains No Chlorofluorocarbons."
  - "Use With Confidence. Contains No Fluorocarbons Claimed to to Harm the Ozone Layer."

  These statements appear on containers of products that were propelled by CFCs prior to the ozone depletion announcement, as well as those that were not. Clearly, a differentiation must be made between this "positive" label and the "negative" label which was required by Federal agencies on CFC-propelled products. Positive and negative here reflect the marketers' impression of the effect of the label on consumer sales.

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*Sources: Newspapers and Schiff [69]. It was impossible to obtain a copy of the CPSC survey.

Chapter XII

THE SAFETY OF ALTERNATIVE PROPELLANTS

The safety of aerosol products is a complex and controversial issue that has come under close public scrutiny in recent years. An understanding of the safety issue involves a three-step process. First, the physical hazards of aerosol packages and their ingredients must be examined in relation to their manufacture, transportation, storage, use, and misuse. Second, the acute physiological effects of the ingredients must be assessed. (The issue of long-term health effects such as carcinogenesis is outside the scope of this report.) Third, the nation's experience with aerosol hazards, as reported in accident, injury, and mortality statistics in transportation, manufacture, and consumer use, must be analyzed.

To pinpoint the impact of the regulation on aerosol product safety, data on each of these topics for each of the propellant systems would be needed. The data, however, were not available, nor was the generation of such data possible. The scattered bits of data, which were available but which had been generated for a purpose other than comparing the safety of propellant systems, had to be pieced together to compile a picture of the comparative safety of alternative propellants in terms of their physical hazards and physiological effects.

PHYSICAL PROPERTIES OF AEROSOL SYSTEMS

The reformulation of products containing the CFCs that were banned involved changing propellants from the banned CFCs to HCs, compressed gases (such as nitrogen or carbon dioxide), and CFC-152a. Compressed gases and CFC-152a have had limited use due to the poor spray characteristics of the former and the high cost of the latter. Thus, the ban has primarily resulted in a shift from the use of CFC-11, -12, and -114, which sometimes had been blended with HCs prior to regulation, to HCs (such as propane and isobutane), to which methylene chloride is often added as a flame retardant.

The physical hazard of an aerosol product is dependent on a number of factors: the propellant, solvent (if any), active ingredients, flame suppressants, the valve, and the container. Prior to, during, and after use, aerosols are often subject to heat, open flame, puncture, and compression. The unique properties of each aerosol package determine the degree of physical hazard presented by the aerosol product. This chapter attempts to evaluate the hazards presented by the aerosol package, especially the effect of the ban on these hazards.

Flammability

A gas is considered to be flammable if it forms flammable mixtures with air. Each flammable gas has a certain concentration range in air at which a flammable mixture is formed. In the laboratory, the flammability of a mixture of gas and air is determined by mixing known amounts of gas and air in a drum or a tube, and exposing the mixture to a source of ignition. The flammability of a gas is reported in terms of its upper and lower flammability limits expressed as a volume percent of air. The flammability of various propellants is given in Table XII-1.

It is obvious from examining Table XII-1 that most CFCs are nonflammable. As a result, prior to 1974, CFCs were used in any aerosol product in which their flame-retardant property was viewed as of critical importance. HCs were the chief propellant in aqueous-based products in which flame-suppressant features were less important. CFCs were the primary propellant in spray cooking lubricants, pharmaceutical products, some industrial products, and in most alcohol-based personal products (hairsprays, antiperspirants, deodorants, and colognes). HCs were used in water-based aerosol products such as shaving lathers, window cleaners, spray starches, room deodorants, and space insecticides.

Sometimes HCs were blended with CFCs prior to regulation in order to take advantage of both the lower cost of HCs and also the flame-retardant properties of CFCs. The results of blending are illustrated in Graph XII-1.

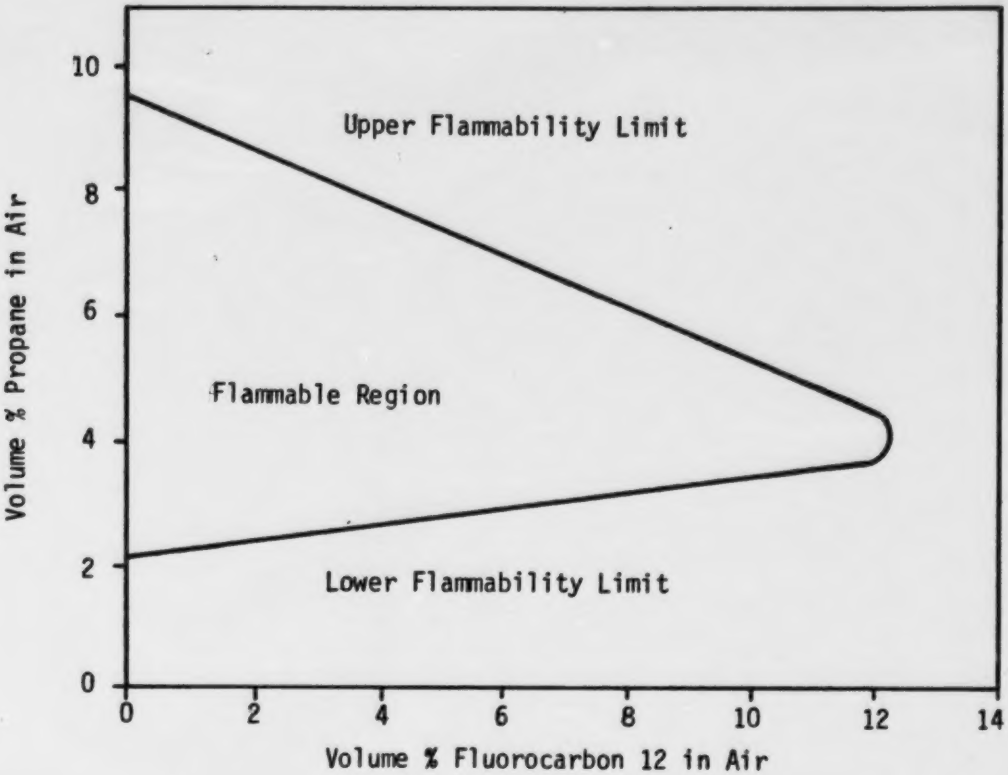
The flammability of the base liquid (active ingredients plus solvent, if any) is evaluated by its "flash point". The standard method of determining the flash point of an aerosol is to puncture a can so that all of the propellant is released. Then, the base liquid is chilled well below zero degrees F, and poured into a chilled cup. The cup is then warmed slowly

Table XII-1

FLAMMABILITY LIMITS OF VARIOUS PROPELLANTS IN AIR

Propellant	Formula	Flammability Limits in Air (vol. %)
CFC-11	CCl_3F	nonflammable
CFC-12	CCl_2F_2	nonflammable
CFC-21	$CHCl_2F$	nonflammable
CFC-22	$CHClF_2$	nonflammable
CFC-114	$CClF_2CClF_2$	nonflammable
CFC-123	$CHCl_2CF_3$	nonflammable
CFC-124	$CHClFCF_3$	nonflammable
CFC-133a	CH_2ClCF_3	nonflammable
CFC-134a	CH_2FCF_3	nonflammable
CFC-32	CH_2F_2	nonflammable
CFC-31	CH_2ClF	10-27
CFC-141b	CH_3CCl_2F	6.4-15.1
CFC-142b	CH_3CClF_2	6.0-15.0
CFC-152a	CH_3CHF_2	3.9-16.9
Propane	C_3H_8	2.2-9.5
n-Butane	C_4H_{10}	1.9-8.5
Isobutane	C_4H_{10}	1.8-8.4
n-Pentane	C_5H_{12}	1.4-8.3
Isopentane	C_5H_{12}	1.4-8.3
Methylene chloride	CH_2Cl_2	12-19
Methyl chloroform	CH_3CCl_3	6.8-15.5
Dimethyl ether	CH_3OCH_3	3.4-18.0

Source: Sanders, p. 232-3.



Graph XII-1. Flammability Limits of Propane in Fluorocarbon 12/Air Mixtures.

Source: Sanders, p. 237.

(2° F/min.), and a taper or electronic ignition source is passed over the cup periodically. The temperature of the liquid when it first bursts into flames is the flash point. Liquids with low flash points are more flammable than those with higher flash points. The flash point of some commonly used aerosol solvents are: diethyl ether, -40° F; isopropanol, 70° F; and isopropyl myristate, 200° F. Water, of course, has no flash point. There is no evidence to suggest that reformulation involved widespread changes in solvents, so that changes in the flammability of the product based on its flash point are considered to be minimal.

The flammability of the aerosol product (including both propellant and solvent) during use is assessed by the flame extension test. In this test, spray from a test can is directed at a candle flame positioned six inches from the valve, and perpendicular to the direction of spray. The parameters measured are called "flashback", which is the number of inches the flame is extended toward the can, and "flame projection", which is the number of inches the flame is extended away from the can.

The Federal Hazardous Substances Labeling Act requires aerosol containers to be labeled "FLAMMABLE" if the flame projection exceeds 18 inches, or if the base liquid has a flash point between 20° and 80° F. Containers must be labeled "EXTREMELY FLAMMABLE" if the flashback reaches to the valve, or if the flash point of the base liquid is below 20° F. Other Federal, state, and local codes require additional warnings on the label.

Since the ban on CFCs as aerosol propellants, methylene chloride has been used to reduce flame propagation. The addition of 15 percent methylene chloride as a solvent in hairsprays, for instance, can easily reduce the flame distance by 2 or 3 inches. As skin irritations can result from the use of methylene chloride, a 10 to 20 percent limit is recommended for most personal care products, and it is not used in antiperspirants. The addition of methylene chloride has been shown to reduce a formulation's flammability status in the flame projection test. However, because methylene chloride is flammable itself, it is possible that it would be seen to be more flammable if a different test were used.

In addition to using methylene chloride, manufacturers of aerosol products have changed valve designs in order to reduce flame propagation. For example, the vapor tap valve is a conventional aerosol valve with a small hole, or tap, in its stem to allow gaseous propellants, as well as liquid product, into the nozzle. Product dilution by the propellant causes a lower delivery rate (of the product), finer dispersion of the droplets, and a coarser spray. These factors lead to a reduction in flame propagation. It is not uncommon for an aerosol which exhibits a flame projection of 30 to 36 inches with a standard valve to project 18 inches or less with a vapor tap valve. The coarse spray associated with the vapor tap valve is considered less desirable from a marketing perspective; this has been alleviated by reducing the size of the orifice (final opening) of the valve. The use of lasers for boring orifice holes has enabled a reduction in orifice size of over 90 percent in some instances.

Although vapor tap valves were available prior to the ban, their use was limited to products in which a fine dispersion was desired. Reformulation has led to considerable growth in the use of this valve. They are used extensively in personal products and in most industrial products.

As a result of the ban, industry's attempts to reduce the problems of flammability seem to have concentrated on improving the flame extension test performance through the addition of methylene chloride and employing alternative valves. There is no evidence to indicate that reformulation was directed toward a reduction in either flammability limits or flash points. Efforts to reduce flame extension were aimed at reducing the hazards attendant to the actual use of aerosol products, and not to the hazards of filling, storing, shipping, or disposal.

The report "The Explosive Hazards Attendant to the Use and Common Misuse of Aerosol Cans" [64], prepared by the Cornell Aeronautical Laboratory (CAL) for the National Commission on Product Safety in 1969, was used in this analysis to estimate the state-of-the-art in aerosol packaging prior to the ban, and to assist in projecting changes as a result of the ban. As seen in Table XII-2, sixteen products were tested for the following characteristics: flame projection, pressure at 130° F, and (cold) burst pressure. Of the products tested, seven exhibited no flame projection, four were 18 inches or less, and five were greater than 18 inches. In each of the five extremely flammable products, the solvent was highly flammable. This evidence suggests that the solvent is at least as important as the propellant to the results of the flame projection test.

Explosive Hazards

Another physical determinant of safety is the behavior of a can or a large number of cans exposed to heat and/or open flame. This is useful when considering the safety of aerosol products during transportation, storage, and disposal. Because the product consists of a liquid and a gas in a tightly sealed and pressurized container, exposure to heat increases the can's internal pressure. The potential for injury exists when the pressure exceeds the burst pressure of the can. DOT regulations require that pressure in an aerosol can not exceed 140 psig at 130° F, and that cans be able to withstand this internal pressure.

Table XII-2

SUMMARY DATA ON CORNELL AERONAUTICAL LABORATORY TESTING PROGRAM

Type	Trade Name	Flame Projection	Pressure at 130° F (psig)	Burst Pressure (psig)
Engine Starting Fluid	Permatex Co., Inc.	24+ in.	Not Tested	300
Aluminum Paint	Rustoleum Corp.	18 in.	Not Tested	Not Tested
Engine Enamel	Plasti-Kote Corp.	24. in.	140	Not Tested
Hair Spray "A"	Great A&P Tea Co.	None	95	Not Tested
Oven Cleaner	Easy-Off (Boyle-Midway, Inc.)	None	Not Tested	Not Tested
Furniture Polish	Pledge (S.C. Johnson & Sons)	None	79	400
Shave Cream "A"	Great A&P Tea Co.	None	120	Not Tested
Choke Cleaner	Y's Buy Chemicals	27 in.	Not Tested	Not Tested
Tanning Lotion	Coppertone (Plough, Inc.)	20 in.	112	308
Ant and Roach Killer	Black Flag (Boyle-Midway, Inc.)	20 in.	110	210
Bug Killer	Raid (S.C. Johnson & Sons)	None	135	Not Tested
Insect Repellant	Off (S.C. Johnson & Sons)	None	Not Tested	Not Tested
Deodorant	Ban (Bristol-Meyers)	None	109	Not Tested
Hair Spray "B"	Aqua Net (Rayette-Faberge)	18 in.	88	Not Tested
Hair Spray "C"	Hidden Magic (Proctor & Gamble)	16 in.	84	Not Tested
Hair Spray "D"	VO-5 (Alberto-Culver Co.)	4 in.	81	350

Source: R. E. Reinnagel, p. 9-17.

As seen in Table XII-2, the CAL tests demonstrated typical equilibrium pressures at 130° F to be below the 140 psig regulation. Two products approached this limit, but the instrumentation precision limited the researcher's ability to conclude that they were not in compliance. A comparison of these pressures with the burst pressure, which was determined by injecting the cans with compressed air, indicated that the cans were quite capable of withstanding the pressures generated at 130° F. For instance, the temperature required to burst a container which bursts at 210 psig is close to 600° F. Thus, a fairly wide margin of safety has been built into this aspect of container design.

The author of the CAL report cautions that a limiting factor in the evaluation of the burst pressure of a container is the quality in the container construction. One container in the temperature-pressure test burst before the temperature reached 130° F. The fact that the seam of the can split (as opposed to an end popping off) led the author to conclude that the quality control of aerosol packaging should be investigated. In the period 1973 to 1980, the construction of containers has changed almost completely from soldered seams to welded seams. There is no indication that the quality control problem has been eliminated.

Under most storage (and transportation) conditions, the danger involved when a can bursts because of excessive heat would be independent of the flammability of the contents. However, in the event that a source of ignition is near the can when it bursts, an HC-propelled can could conceivably cause a sizeable secondary explosion. A CFC or combined CFC-HC propellant system would be less likely to behave in this manner.

The explosive hazard presented by aerosol cans in the midst of fires, as differentiated from heat only, can occur during the incineration of individual cans or the burning of large numbers of cans under warehouse fire conditions (discussed elsewhere). CAL investigated the behavior of single aerosol cans in rubbish fires, without differentiating between CFC and HC products. Their qualitative findings indicate that exploding cans present a hazard in three ways:

- Cans which are nearly full pop their tops or bottoms and the contents explode in a "fireball". A person within the range of the fireball could be severely burned.

- Cans which are nearly empty split their side seam in a violent explosion which ejects "shrapnel" at a high velocity. The range in which a person could be hit by shrapnel is much wider than that of a fireball.
- All cans which explode send burning debris and/or liquids over an indeterminant range. Fuller cans send more burning liquids over a smaller range; emptier cans send more burning debris over a wider range.

CAL did not quantify the relative explosive hazard of CFCs and HCs during incineration. However, based on what is known of the relative flammability of CFCs and HCs, it is reasonable to assume that the explosive hazard of HCs are greater than those of CFCs.

TOXIC PROPERTIES OF PROPELLANTS

The first comprehensive examination of the acute physiological effects of CFCs concerned the inhalation toxicity of CFCs, and were performed as a result of fatality reports attributed to the use of aerosol products. In the early 1960's, several cases of sudden death among asthmatics were reported in the medical literature. Subsequent epidemiological investigations suggested that the use of bronchodilators might have been linked to these deaths. Bronchodilators were introduced in measured-dose aerosol packages in the late 1950's. Aviado [6] has provided a thorough review of the controversy surrounding these deaths. Researchers are divided between those who attribute the deaths to the active ingredients and those who attribute the deaths to the toxicity of the propellants. One of the most widely employed propellants in these sprays, CFC-11, is considered to be one of the most toxic propellants [7,13]. The relative toxicities of the CFCs and HCs, as determined by Aviado, are illustrated in Table XII-3. Regardless of whether the base liquid or the propellant caused these deaths, asthmatics are considered to be a greater risk to these effects, and in 1968 bronchodilators were no longer available "over the counter".

The toxicity of CFCs was also examined as a result of an "epidemic" in which hundreds of teenagers died in the late 1960's and early 1970's. Seeking

Table XII-3

SUMMARY OF PATTERN OF EFFECTS ON CIRCULATORY AND RESPIRATORY SYSTEMS OF INHALATION OF PROPELLANTS

	Cardiac Arrhythmia			Tachycardia[3]		Respiratory Depression[4]			Broncho-constriction[5]			Decreased Compliance[6]		
	Induce[1]	Sensitize[2]												
Chemical	Mouse	Mouse	Dog	Dog	Monkey	Rat	Dog	Monkey	Rat	Dog	Monkey	Rat	Dog	Monkey
Propellants of High Toxicity														
CFC-11; Trichlorofluoromethane	++	++	++	++	++	++	+	+	++	0	0	++	0	0
Propellants of Intermediate Toxicity														
CFC-114; Dichlorotetrafluoroethane	0	+	+	+		0	0		+	+		+	+	
CFC-12; Dichlorodifluoromethane	0	0	+	+	0	+	+	+	0	+	0	+	+	0
Isobutane	0	+	+	0		++	+		++	+		++	+	
Propane	0	++	+											
Propellants of Low Toxicity														
CFC-152a; Difluoroethane	0	0	+	0	0		0	0		0	0		0	0

++ = Response at lower concentration; + = Response at higher concentration; 0 = Absent or opposite response.

Source: Aviado [6].

1. Induces abnormally irregular heartbeat.
2. Sensitizes the heart to the arrhythmia induced by epinephrine, a heart-stimulating hormone which is released during heavy exercise.
3. Induces abnormally rapid heartbeat.
4. Decreases the quantity of air breathed per unit of time, due to either depressed capacity or frequency of breathing.
5. Constricts bronchi (lower airways), stimulating an asthmatic condition.
6. Decreases the elasticity and, therefore, the capacity of the lungs.

the euphoria which CFCs are known to provide upon inhalation, it became popular to spray certain spray cooking lubricants, antiperspirants, and first aid products into plastic bags or pillows, and then "sniff" (actually inhale deeply) the contents of the pillow or bag. Death, which often resulted, was independent of prior use or the amount of material inhaled. Death occurred so suddenly that many victims died before they could take their head out of the bag. The rash of "sudden sniffing deaths" prompted a thorough investigation of the toxicological properties of all propellants in use.

Bass [12] attributed these deaths to cardiac arrhythmia, based on case studies of several sudden death victims. Test animals exposed to a wide variety of HCs and CFCs experienced cardiac sensitization, a condition which could produce arrhythmia and death [63], when exposed to epinephrine. Another study indicated that the high-pressure propellants (isobutane, methylene chloride, CFC-11, CFC-114) affected circulation (blood pressure, heart rate), while low-pressure propellants (propane, CFC-12, CFC-152a) affected respiration (pulmonary resistance and compliance). As seen in Table XII-3, the most toxic of these were found to be CFC-11 and CFC-12, the least toxic, CFC-152a [7,13]. Taylor's [71] research has suggested that a predisposition to heart disease could enhance the risk of arrhythmia during exposure to CFC-11.

Because PAM, a vegetable oil spray consisting of lecithin, CFC-11, and CFC-12, was involved in many sudden sniffing deaths, its effects on lung tissue were examined [30]. The exposure of lung tissue to PAM resulted in a disintegration of normal alveolar surfactant, leading to extensive alveolar collapse. The authors suggest that the danger of hypoxaemia from alveolar collapse might occur at concentrations too low to cause cardiac arrhythmia. The combination of CFCs and lecithin was found to be more toxic than either substance by itself.

In a detailed study of the acute and chronic toxicity of aerosol products under its jurisdiction, the CPSC found that there are four chlorinated solvents which have been widely used in aerosol products.* These are methylene chloride, methyl chloroform, trichloroethylene, and tetrachloroethylene. These solvents all have flame-suppressing qualities in addition to their properties as solvents. The study noted that in coating and finishing aerosol products, methylene chloride was the most commonly used chlorinated solvent, whereas, for household and automotive products, methyl chloroform was most common. The use of trichloroethylene and perchloroethylene was reported to be diminishing because of the threat of potential long-term health effects. In fact, of the four, only methyl chloroform has not been linked to carcinogenic activity.

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*CPSC Memorandum on Aerosol Consumer Products, September 3, 1981.

The effect of the ban on the prevalence of these and other solvents in the marketplace cannot be determined. However, industry representatives have indicatd that in personal care products, methylene chloride has been widely used to reduce the flammability of HC propellants. Although methylene chloride is not generally regarded as being highly toxic, poisonings have been reported.* Methylene chloride affects central nervous system function and interferes with the oxygen-transporting ability of hemoglobin. Because methylene chloride has demonstrated evidence suggesting carcinogenicity and because of its widespread use, methylene chloride is presently the subject of an intensive two-year animal bioassay being conducted by the National Cancer Institute and Dow Chemical Company.

Thus, the net effect of the ban of CFCs has been to replace propellants of "high" and "intermediate" toxicity with those of "intermediate" toxicity. The increased use of methylene chloride and other chlorinated solvents as flame suppressants is impossible to assess on the basis of extremely limited data. Similarly, the toxicity of the thousands of other ingredients used in aerosol products both before and after the ban cannot be determined.

ACCIDENT RECORDS

To estimate the national extent of injuries and fatalities related to the use of aerosols, data collection was divided into three sectors: transportation, manufacture, and consumers. Transportation data includes that which is collected by the Department of Transportation (DOT), which describes the accident rate involved in shipping aerosol products. Manufacturing data includes that which is collected by the Department of Labor (Federal and state), which describes the experience of employees engaged in the filling, packaging, warehousing, sale, use, and disposal of aerosol packages. Data for the consumer sector was collected by CPSC and describes the injury and fatality rates attendant to the nonoccupational storage, use, abuse, and disposal of aerosol products. Although in several of these areas actual rates were impossible to estimate, the trends provide a clear picture of the ban's effects on the safety of aerosol products.

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*Ibid.

Transportation

The Department of Transportation maintains a computer file on reports of commercial transportation accidents involving a death, an injury requiring hospitalization, or at least $50,000 in property damage. A list of accidents from 1973 to 1979 involving the shipping of aerosol products was obtained. The limited information presented by this data prevents any conclusions from being drawn as to the role of propellants in the accident.

It is estimated that less than 4 percent of the 11.5 billion pounds of propane and isobutane produced annually is used in the filling of aerosol units. Less than one-half of this, or 2 percent, is ban-related, so it is unlikely that this would significantly affect the safety of bulk shipments of these materials.

Manufacturing

BLS collects worker injury and fatality statistics through its Supplementary Data System. Each year, the records of over two million accidents are compiled by this system. However, the resolution available in these records is quite limited, and identifiers such as "pressurized container injury" are not available. Without such an identifier, the BLS data was found to be useless for the purposes of this analysis. Representatives of the 50 states reporting to the Supplementary Data System were polled, as was the BLS Work Injury Report System (which conducts projects in special areas), to determine if an analysis of worker injuries had been conducted. No such analysis had been performed, nor were any of the states' systems able to identify aerosol injuries.

The Occupational Safety and Health Administration (OSHA) collects data on inspections and citations, which are pursuant, in some cases, to accidents in the work place. For the purposes of this investigation, the computer files were searched in the following manner: all inspections and citations that were related to an accident involving any of ten propellants were identified for the period July 1, 1976 to June 30, 1979. To limit the scope of this investigation to industries involved in aerosol filling and storage, three SICs were selected as being representative of those affected by the ban:

- 2834 Pharmaceutical preparations
- 2842 Specialty cleaning, polishing, and sanitation preparations
- 2844 Perfumes, cosmetics, and toilet preparations.

No inspections or citations in any of these SICs identified any of the propellants as a hazardous substance involved in an accident. Thus, no specific statistics are available to describe the injury or fatality rate attendant to the manufacture, storage, use, or disposal of aerosal products in industry.

Several organizations collect case histories of industrial fires and explosions for specific purposes. Collections which were investigated for this analysis include the Factory Mutual Research and Engineering Corp., the National Fire Protection Association, and the U.S. Fire Academy. It should be emphasized that none of these collections attempted to include all fires in any category; instead, they are intended to be used as descriptions of types and trends of the fires and explosions of interest. A survey of the information available in these reports indicated that even in the cases of fires involving aerosol filling or storage, the role of aerosol containers or propellants in the fire was often not specified. It was therefore determined that these reports would be of limited use in the identification of hazards attendant to the manufacture, filling, sale, and storage of aerosol products.

To gain a better understanding of the nature of industrial fires and explosions in the aerosol industry, the reports of several specific fires were investigated for this study. Based on news reports, industry sources, and OSHA Area Office files, specific details as to the origin, control, and extent of damage were obtained for each fire. A summary of this investigation appears in Table XII-4.

Although the sample is small (16 observations), several trends emerge. Six fires were started by the ignition of flammable vapors (solvents) which had escaped from vessels in the mixing area of aerosol filling operations. Half of these fires occurred before 1976 when CFCs were still in use. Five fires were started by the ignition of leaking HC propellant; one occurred during delivery of the propellant, the other four started on the filling line. One occurred before 1976, and the other four occurred after 1976.

In 1977, one small explosion severely injured a laboratory technician who was allegedly reformulating a hairspray. Two fires since 1976 began during the disposal of large quantities of returned or rejected products. Since 1976, three fires, resulting in $82 million damage and 52 injuries, occurred in areas used to store aerosol units. Although each of these fires started in an area which was not used for aerosol storage, in all three cases the fires went quickly out of control as soon as the fire reached the aerosol can storage area.

Factory Mutual Tests. The largest of these fires, an $80 million fire at the Pathmark Distribution Center in Edison, New Jersey, seems to have prompted Factory Mutual to perform a series of tests in 1980 which simulated actual warehouse fire conditions. The tests were performed to determine what, if any, new storage configurations or requirements for automatic sprinkler activation or water delivery rates should be imposed on the warehouses they insured. It should be noted that most major insurers impose the specifications that Factory Mutual develops. The tests were conducted as follows.*

Cans containing three formulations designed to simulate a wide variety of aerosol products were packed in boxes and stacked on pallets. The first formulation consisted of 65 percent water and 35 percent HC propellant, and represented window cleaners, air fresheners, and some insecticides. The second was made up of 65 percent alcohol and 35 percent HC propellant, a mixture similar to that found in hairsprays and disinfectants.

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*H. C. Scouteguazza, Factory Mutual Research Division, written communication of September 23, 1980.

Table XII-4

SUMMARY OF SELECTED INDUSTRIAL FIRES RELATING TO THE MANUFACTURE AND STORAGE OF AEROSOL PRODUCTS

Chase Products Co., Broadview, IL, January 8, 1969. Explosion of a vessel of flammable liquid on the filling line sprayed burning liquid over a wide area. Seven deaths; property damage, $50,000.[1]

American Aerosols, Inc., Holland, MI, October 14, 1969. Explosion and fire caused by leaking hose during propane delivery destroyed tank farm and several vehicles. Five injuries; property damage, $100,000.[2]

Barr Co., Niles, IL, January 25, 1974. Series of explosions in mixing area when vapors from mixing tank (product: furniture polish) were ignited by spark from an electric motor. Two injuries; property damage, $500,000.[3]

Connecticut Aerosols, Inc., Milford, CT., June 4, 1974. Explosion in mixing area when vapors from mixing tank were ignited by spark from an electric motor. Twenty-one injuries; property damage, $40,000.[4]

Accra-Pak, Inc., Elkhart, IN, January 7, 1976. Series of explosions on filling line caused by HC leak to be ignited by electrical spark. Two deaths; eighteen injuries; extensive property damage.[5]

Hysan Inc., Blue Island, IL, April 8, 1977. Explosion in mixing area when vapors from a mixing tank were ignited. Four injuries; property damage, $1,750,000.[6]

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[1] Fire Report: Broadview, IL Fire Department, January 8, 1969. National Fire Protection Association Fire Report: Broadview Fire Department.

[2] Fire Report: Holland, MI Fire Department, October 14, 1969. Conversation with Chief Marvin Mokman, Holland Fire Department, December 4, 1980.

[3] Fire Report: Fire Prevention Bureau, Niles, IL, January 29, 1974. Conversation with Chief Albert Hoelble, Niles Fire Prevention Bureau, December 29, 1980.

[4] Fire Report: Milford, CT Fire Department, June 14, 1974. Conversation with Chief Healey, Milford Fire Department, December 29, 1980.

[5] Fire Investigation Report: Elkhart, IN Fire Department, January 12, 1976. Safety and Health or Accident Inspection Report, CSHO No. C7224, Report No. 36, U.S. Department of Labor, Occupational Safety and Health Administration, Indianapolis Area office. Indianapolis Area Office files, U.S. Department of Labor, Occupational Safety and Health Administration.

[6] Basic Field Incident Report: Blue Island, IL Fire Department, April 8, 1977. Conversation with Chief Robert Schultze, Blue Island Fire Department, December 30, 1980. Safety and Health or Accident Inspection Report, CSHO No. H6098, Report No. 51, U.S. Department of Labor, Occupational Safety and Health Administration, Chicago Area Office.

Table XII-4

(Continued)

S. C. Johnson & Son, Racine, WI, July 17, 1977. Explosion in mixing area caused by ignition of vapors from mixing tank. All motors were explosion-proof. One injury; property damage, $100,000.[7]

J. H. Breck Co. (now Shulton, Inc.), West Springfield, MA, August 12, 1977. Explosion in laboratory during flammability test on hairspray can. Exhaust hood was not in operation, and a match struck by technician ignited accumulated gases. One injury; no property damage.[8]

Avon Products, Inc., Newark, DE, January 25, 1978. Explosion when HC vapors in aerosol can compactor were ignited by forklift. Two deaths; 8 injuries; extensive property damage.[9]

U.S. Co., Niles, MI, November 25, 1978. Fire of unknown origin in employee rest area; spread to aerosol storage area. Fire was spread and sustained by exploding (automotive) cans. No injuries; property damage, $1,000,000.[10]

Pathmark General Merchandise Division, Edison, NJ, January 17, 1979. Warehouse fire of suspicious origin spread rapidly, due primarily to explosions of aerosol cans. No injuries; property damage, $80,000,000.[11]

Zoe Chemical Co., Inc., New Hyde Park, NY, November 5, 1979. Explosion in mixing area caused by ignition of vapors from mixing tank (product: household floor wax) by spark from an electric motor. Five injuries; extensive property damage.[12]

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[7] Fire Incident Report: Mt. Pleasant Fire Department, Racine, Wisconsin, July 17, 1977. Conversation with Chief Robert Cole, Mt. Pleasant Fire Department, December 30, 1980.

[8] Report of Operations: West Springfield, MA Fire Department, August 12, 1977. Conversation with George McCarthy, West Springfield Fire Department, December 30, 1980.

[9] Conversation with Susan Kruer, State Firemarshall's Office, State of Delaware, December 29, 1980.

[10] Incident Report: Howard Township Fire Department, Howard County, Michigan, November 25, 1980. Conversation with Chief Dean Curtis, Howard County Fire Department, December 10, 1980.

[11] Fire Report: Edison, NJ Fire Department, January 18, 1979. Conversation with H. Ray Vliet, Edison Fire Department, December 12, 1980.

[12] Personal communication with J. Epps, Area Director, U.S. Department of Labor, Occupational Safety and Health Administration, Westbury, New York.

Table XII-4

(Continued)

Chase Products Co., Broadview, IL, November 7, 1979. Explosion due to HC leak on filling line ignited by spark from an electric motor. Twelve injuries; property damage, $8,000.[13]

American Cyanamid Co., Fort Washington, PA, November 17, 1980. Explosion in garbage truck which was "packing" several cases of aerosol containers. No injuries; damage to truck, $92,000.[14]

Radiator Speciality Co., Indian Trail, NC, November 26, 1980. Explosion caused by HC leak on filling line being ignited by spark from an electric motor. Fire was spread by exploding aerosol cans. Two deaths; 52 injuries; property damage, $1,000,000.[15]

Aerosol Research Laboratories, Division of Barcolene Corp., Holbrook, MA, October 22, 1981. Explosion caused by HC leak on filling line being ignited by maintenance worker (product: room air freshener). Four deaths; 20 injuries; property damage, $1,000,000.[16]

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[13] Alarm Response Record: Broadview, IL Fire Department, November 7, 1979. Safety and Health or Accident Inspection Report. CSHO No. 142. Report No. 80. U.S. Department of Labor, Occupational Safety and Health Administration, Chicago Area Office.

[14] Fire Report: Fort Washington, PA Fire Company, November 12, 1980. Conversation with William McClintock, Fort Washington Fire Company, November 21, 1980.

[15] Fire Inspection Report: Union County, NC Emergency Services, November 26, 1980. Fire Report: Union County Department of Inspection, December 12, 1980. Conversation with Hampton Funderburke, Union County Emergency Services, December 30, 1980.

[16] Latest available estimates as this report goes to press provided by Lieutenant Gerard Blais, Holbrook Fire Department, conversation of October 27, 1981.

The third consisted of 65 percent toluene (an HC solvent) and 35 percent HC propellant, as in paints, engine cleaners, and some insecticides. None contained CFCs, since they were banned as aerosol propellants in late 1978.

Cases of each formulation were segregated and stacked on standard warehouse pallets. For some tests, pallets were stacked up to four high to simulate warehouse conditions. A small fire was started at the base of the pallets, and the ensuing fire was observed to determine whether the automatic sprinklers could keep the fire under control.

This test indicated that water-based products could be contained by warehouse sprinklers built to existing specifications. Although the intense heat caused cans to explode and fly through the air, no additional fires were started. This test allegedly caused Factory Mutual personnel to conclude that propellant flammability is not a problem in fires of this sort. The test conducted on the second formulation indicated that alcohol-based products fires can only be controlled when stacked pallets have sprinklers between each layer in the stack. Several "satellite fires" were caused by exploding cans flinging burning liquids to remote areas. As a result, Factory Mutual now recommends that alcohol-based products be floor-stacked only five feet high. Pallets may be stacked up to three pallets high only when each tier is provided with sprinklers. In addition, cyclone fencing is recommended around the area to restrain flying debris.

The test conducted on the third formulation indicated that a sprinkler system similar to that used in the second formulation, but at twice the normal water delivery rate, is necessary to contain a toluene-based product fire. In addition, cyclone fencing or a firewall is recommended around each rack of pallets.

The aerosol industry has criticized these tests because many aerosol products such as antiperspirants do not fit neatly into any of the three categories. A typical antiperspirant formulation is 80 percent propellant, with small amounts of volatile oils, aluminum complexes, and perfumes. In a separate Factory Mutual test, a single pallet of antiperspirant burned fiercely and almost completely before the sprinkler was able to extinguish the blaze. As a result of this test, Factory Mutual has changed its classification of antiperspirants from water-based to alcohol-based.*

The Effect of the Regulation on Industrial Safety. Several conclusions can be drawn concerning the effect of the regulation on the level of industrial safety. There is no reason to expect any safety impact in the chemical sector, nor in valve and container manufacturing. The HC and transportation sectors were not affected because no new processes were prompted by regulation, and because the increase in volume of HCs handled was not appreciable.

With respect to safety, the impact of regulations on aerosol filling operations has been significant for both custom fillers and marketer-fillers. It has been historically established that HC handling operations require rigorous safety precautions. Fillers were required to conform to stringent safety standards, which included the installation of explosion suppression systems, blow-out walls, explosion-proof walls and roofs, spark-proof electrical equipment, and HC-detection devices. With the installation of the appropriate safety systems, HC filling can be considered nearly as safe as CFC filling.

As a result of the ban, the number of facilities engaged in HC filling increased suddenly. In some cases, HC filling was begun before the proper safety devices were installed; as a result, there were at least three fires from 1976 to 1980 in which a leak on the filling line was ignited by an electrical spark. Had proper equipment been employed, a spark from electrical equipment would have been impossible. Thus, for fillers, one result of the ban has been an increased hazard due to the lag time between change in propellant and upgrading the facilities. In addition to these effects, fillers who retrofitted for the safe use of HCs incurred considerable investment costs for new equipment, as discussed in Chapter VIII. The additional insurance costs incurred by HC fillers is also discussed in these chapters.

The effect of the ban on hazards related to warehousing and storage remains unclear. The Factory Mutual tests indicate that in warehouse storage, water-based HC-propelled products can present a serious hazard. In any class of HC-propelled products, storage in an area equipped with inadequate sprinklers or the presence of workers during the initial phases of the fire are potentially disastrous situations. Alcohol-based HC-propelled products have proven to be even more hazardous, leading to the conclusion that the storage of these products is, in most cases, inadequate. The tests indicate that HC-propelled antiperspirants present a previously unrealized hazard of extreme flammability, and that petroleum-based, HC-propelled aerosol containers are stored, in most cases, under totally inadequate conditions.

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*Antiperspirants had been classified as water-based because the solvent, isopropyl myristate, has a flash point of over 200° F, and is thus considered to be "nonflammable".

The behavior of CFC products under warehouse conditions has yet to be tested. The nonflammability which was touted prior to the ban was based on the flame extension test, which has proven to be an inadequate indicator of total package flammability. CAL performed tests on individual cans to simulate their behavior in conflagrations [64]. Eight full cans were set in 6 ounces of gasoline, which was ignited. Five of the cans (some of which had no flammability warning on the label) burst or exploded. Two cans of hairspray burst violently, popping their tops with enough force to lift a 20-pound case two feet in the air. This test indicated that exposure of full cans to intense heat and flame result in a "fireball" effect. Although both HC and CFC products were tested in all of the CAL tests, no attempt was made to distinguish between the behavior of each.

In summary, while the hazard presented by HC warehousing today is significant, a lack of data on CFCs prevents quantification of a change in the level of hazard posed by storage. Assigning the recurring costs of increased insurance rates and the initial investment costs of added safety equipment to regulation is hampered by two uncertainties:

- Whether the regulation instigated these costs;
- Whether the proposed requirements for safety precautions will indeed be enforced.

Consumer Safety

CPSC maintains the most reliable and comprehensive data base on nonoccupational injuries and fatalities. CPSC data is based on three sources. The first is the National Electronic Injury Surveillance System (NEISS), a computer-based network of 71 selected hospital emergency rooms across the country. These emergency rooms are statistically selected for inclusion in estimator equations to illustrate the national experience. Data on any injury involving a consumer product is transmitted daily to a central computer. This data includes a profile of the victim and his injury, as well as a description of the product(s) involved.

Because little information concerning the sequence, or cause, of the accident is transmitted, CPSC relies from time to time on in-depth investigations. Initiated by the controversial or hazardous nature of a product, in-depth investigations consist of personal interviews with the victim, the victim's family, or witnesses. Cases are selected for investigation on the basis of frequency and severity of NEISS-reported injuries, as well as CPSC priorities. Hence, the results of in-depth investigations are not based on random samples and cannot be construed as actual rates.

The third source of CPSC data is the Death Certificate Project, in which selected death certificates are examined to provide additional information concerning hazard patterns. Certificates are selected (by participating states) based on "external cause of death" classifications in which consumer products are likely to be involved (burns, falls, lacerations). Since not all death certificates are examined, and because many death certificates fail to note consumer products, the data collected through the project generally understates product-related deaths. Although in some cases death certificates can be adjusted to provide national estimates, these data are only used in this analysis to illustrate trends and to compare relative hazards.

In response to the growing use and the increasing injury rates of aerosol products, CPSC prepared two "hazard analyses", one published in 1974 [20], and the other prepared in draft form in 1977 [10]. These reports employed all of the above data sources to describe the national experience of aerosol injuries. The CPSC provided JACA with additional data to assist in this investigation. National injury rates were based on NEISS estimates in several product categories.* Selected information from all relevant death certificates for the years 1975 through 1979 was also provided. CPSC provided a list of NEISS-reported injuries (complete with "comments") for 1978 and 1979, so that the nature of the injuries could be ascertained.

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*From 1973 through the third quarter of 1978, NEISS included aerosol containers in the category "pressurized containers", which also included nonaerosol products such as soft drinks and propane cylinders. From the fourth quarter of 1978 through the end of 1980, the "pressured container" category was separated into "aerosol containers" and "nonaerosol containers". Aerosol container injuries for 1978 were estimated by applying the ratio of aerosol to nonaerosol injuries of the fourth quarter to the pressurized container injury rate of the first three quarters.

These data are presented in Table XII-5, and are illustrated in Graphs XII-2 and XII-3. It is apparent that the drastic decline in the production of CFC units has been accompanied by a decline in the mortality rate associated with aerosol products. Similarly, the rates of "pressurized container" injuries and "aerosol container" injuries appear to follow the trend of HC unit production. It should be noted, however, that the limited number of data points is insufficient for any definitive conclusions to be drawn from this data.

Injury Rates. The "gross hazard pattern" of injuries from a common source is a means of separating a large number of injuries into groups based on the nature of the accident. In this way the relative distribution of injuries according to type of accident can be obtained. Table XII-6 provides the gross hazard pattern for aerosol injuries in 1975, 1978, and 1979. The estimates for 1975 were provided by an in-depth analysis performed by CPSC in 1978. The estimates for 1978 and 1979 were derived by reviewing "comments" from CPSC injury reports for these years. The injuries are divided into the following five categories: accidental spraying (into eyes or face), mechanical (struck by or fell over container), explosion-ignition (incineration, vapor ignition, or explosion upon dropping or puncture), and ingestion-inhalation (ingestion by child, "sniffing", allergic/sensitization reaction, overcome by fumes). What is immediately apparent is that from 1975 to 1979 the percentage of injuries related to explosion/ignition increased six-fold. Mechanical injuries doubled during this period while ingestion/inhalation injuries remained the same, and spraying accidents were decreased by one-third. It is impossible to project, based on the data presented in Table XII-6, estimates of the number of injuries occurring nationally in each of the four categories, as the estimator equations used to make these projections were not available for this analysis.

The severity of injuries in the four categories was estimated for 1975 by the percent of injuries which resulted in hospitalization. These estimates indicate that the severity of explosion/ignition injuries is over five times that of spraying injuries, and twice that of ingestion/inhalation

Table XII-5

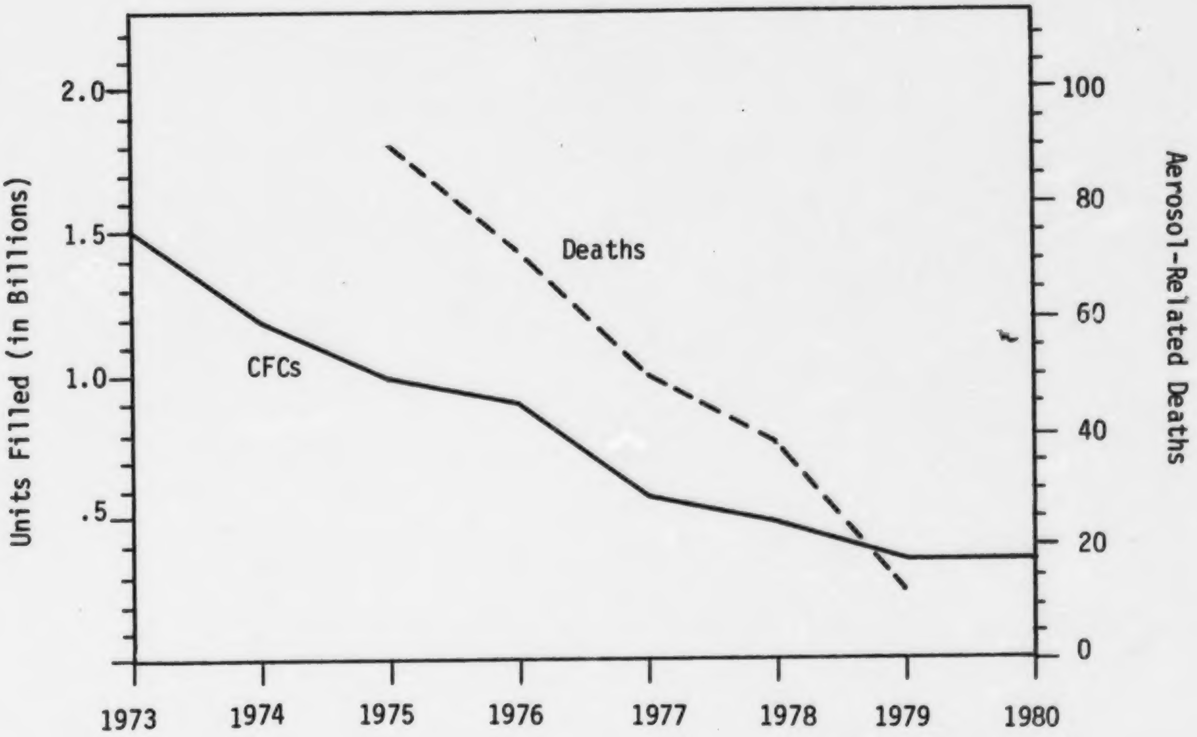
U.S. AEROSOL UNIT PRODUCTION AND CPSC INJURY AND MORTALITY RATES, 1973 TO 1980

	1973	1974	1975	1976	1977	1978	1979	1980
Total Containers Filled (billion units)	2.9	2.7	2.3	2.2	2.1	2.3	2.4	2.2
CFC Units Filled (billion units)	1.5	1.2	1.0	0.9	0.6	0.5	0.4	0.4
HC Units Filled (billion units)	1.4	1.5	1.4	1.4	1.5	1.8	2.1	1.8
"Pressurized Container" Injuries*	6,239	4,400	5,656	5,798	6,059	5,986	10,110	11,074
"Aerosol Container" Injuries	NA	NA	NA	NA	NA	3,570	4,694	4,318
Aerosol-Related Fatalities	NA	NA	89	71	48	37	12	NA

*"Pressurized Container" injuries include injuries from both aerosol and nonaerosol containers.

NA = Not Available.

Sources: CPSC and CSMA.



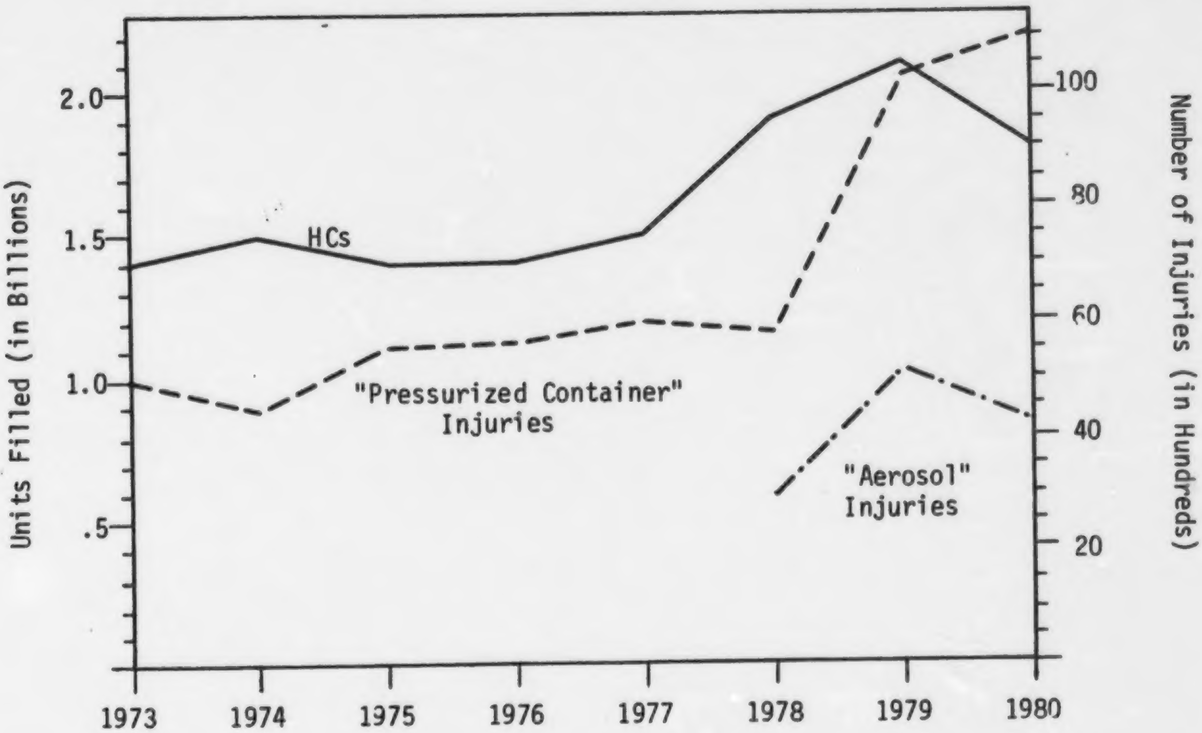
Graph XII-2. CFC Units Filled and Aerosol-Related Deaths, 1973-1980.
Sources: CPSC and CSMA.

Table XII-6

SOURCES OF AEROSOL-RELATED INJURIES OBSERVED IN HOSPITAL EMERGENCY ROOMS

	Source of Injury			
Year	Spraying	Mechanical	Explosion-Ignition	Ingestion-Inhalation
1975	66%	10%	3%	12%
1978	49%	14%	24%	13%
1979	44%	24%	20%	11%

Source: CPSC data.



Graph XII-3. HC Units Filled, Pressurized Container Injuries, and Aerosol Injuries, 1973-1980.

Sources: CPSC and CSMA.

injuries. Because of the infrequency and absolute severity of sudden sniffing deaths, the severity of this condition is underestimated by this technique. This estimate of injury severity is consistent with the CAL incineration tests in which fireballs, jagged pieces of shrapnel, and burning debris posed considerable risk to bystanders.

A profile of the causes of these injuries is provided by a CPSC in-depth investigation [10]. Of 33 explosions investigated, six involved products left in an automobile, ten involved products exposed to some other source of heat, 14 involved accidental or intentional incineration, and three involved the rupture of an obviously defective can. Of 21 vapor ignition injuries, three were the result of intentionally puncturing a can, seven resulted from the accidental puncturing of a can near a source of ignition, two were the result of a faulty valve, and nine were the result of using an aerosol spray near a source of ignition. These investigations covered selected injuries that occurred between 1969 and 1975.

A review of "comments" from 1978 reports indicate that of 38 explosions, 14 were attributed to incineration, five were attributed to storage near a source of heat, and 19 failed to provide sufficient information. Two cases of vapor ignition during use were reported in 1978.

The greatest hazard of aerosols, based on injury data, appears to be that of explosion. Incineration and storage near a source of heat are the two most frequent sequences in these accidents. Each of these cases involve the unsuspecting consumer, as well as careless and abusive persons. In many incineration cases, the injured party was presumably unaware of the presence of pressurized cans in the rubbish. Tire inflators and products containing starting fluid are sold without regard to temperatures normally encountered in automobile storage areas. Defective containers are most likely involved in most storage incidents, as the CAL test indicated the temperature necessary to burst most containers is near 600° F.

The effect of the ban on these hazards is impossible to discern on the basis of injury rates, but it becomes apparent upon examination of safety testing of aerosol products. HCs are more flammable and explosive than their CFC counterparts. The hazard presented by an exploding container can only be increased by replacing nonflammable CFCs with HCs. The addition of methylene chloride, which reduces flame propagation somewhat, cannot be seen as limiting the hazards related to exploding containers, as methylene chloride is flammable. The ignition of vapors, as described in flame extension tests, is a hazard which has not increased as a result of the ban. However, valve failure during storage was found to cause an increase in this hazard. The possibility that the accumulation of vapors in enclosed spaces would result in an explosive atmosphere is another hazard which has increased. Thus, the increase in the use of HC-propelled products has resulted in an increase in the fire hazard presented by aerosol products to the consumer. This increased hazard is manifested in the six-fold increase from 1975 to 1979 in percent of aerosol injuries attributed to fires and explosions.

Fatality Rates. The CPSC Death Certificate Project collected as many as 89 death certificates in one year in which aerosol products were positively implicated; this figure is said to be underrepresentative of the actual mortality rate. Table XII-7 provides a breakdown of aerosol fatalities collected by the Death Certificate Project according to gross hazard patterns. Over 90 percent of these fatalities are the result of their deliberate abuse by teenagers seeking the euphoria which is induced by inhaling CFCs. Three percent are poisonings involving children. The remainder consist of two deaths due to explosion/ignition and one death due to a reaction to a bronchodilator.

Table XII-7

NUMBER AND RELATIVE FREQUENCIES OF AEROSOL-RELATED FATALITIES

Year	All Aerosol-Related Deaths	Source of Death: Sudden Sniffing Death	Accidental Ingestion by Children	Explosion Ignition	Broncho-dilator (Sudden Death)
1976	71	70 (99%)	1 (1%)	0	0
1977	48	44 (92%)	2 (4%)	1 (2%)	1 (2%)
1978	37	34 (92%)	2 (5%)	1 (3%)	0
1979	12	12 (100%)	0	0	0

Source: CPSC Death Certificate Project.

The result of the ban on these deaths is impossible to estimate. The numbers in each category except sudden sniffing death are too small to indicate trends in fatality rates. But the sniffing death rate demonstrates a consistent downward trend that closely parallels the decline in CFC unit production during the Seventies. Based on the dramatic decline in the mortality rate during the years 1975 to 1979, it is assumed that abuse of aerosol products diminished during this same period. This assumption is based on the facts that no changes (pharmacological or olfactorial) were made in the CFCs in use, and that HC propellants fail to induce euphoria.*

It is impossible to assign a weight to each of the many factors which led to the decline in CFC abuse. The decline in availability and use of aerosol products, public education through schools and the media, and the greater availability of other abusive drugs are but a few. One effect of the ban was to change the propellant in PAM, the spray cooking lubricant. During the early 1970's, PAM was synonymous with "CFC abuse"; in fact, PAM appeared more often on sudden sniffing death certificates than any other product. It is possible that with the reformulation of PAM and other abused products, teenagers turned their backs on products remaining on the shelves and on other sources of CFCs. On the other hand, it is entirely possible that the decline in aerosol sniffing was caused by factors which were independent of the regulation.

SUMMARY

The flammability of propellants has been found to have increased due to regulation. It is unclear what effect, if any, the changes in reformulation have had on the flammability of the ingredients. The flammability of the products in use (including a combination of propellant and solvent), based on flame extension tests, has not been adversely affected by the regulation. The hazard presented by a bursting container has not increased, except where this occurs in the presence of a source of ignition. The bursting of an HC-containing can presents an imminent explosive hazard which has adversely impacted the safety of aerosol products.

Both CFCs and HCs have been shown to have adverse effects on both circulation and respiration. The more acutely toxic CFCs have been replaced by the less toxic HCs. The effect of the ban on the hundreds of other ingredients which were changed during reformulation has been impossible to ascertain.

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*There have been cases of deaths due to the inhalation of selected petroleum-based products, such as spray paint and varnish. The euphoria-inducing agent in these cases is the solvent, rather than the propellant.

Among the industries affected by the regulation, custom fillers and marketer-fillers were the most severely impacted by the hazards of HCs. In addition to the increased risk of handling HCs, the lag time between conversion and installation of safety equipment was found to be significant. Tests designed to assess the hazards involved in the warehousing of aerosol products indicate that the fire/explosion hazard of HC products is significantly more severe than was previously realized. A lack of data on CFC fires prevents quantification of the extent of the change in hazard due to regulation. Although more stringent safety requirements for aerosol storage are under consideration, it is unclear whether these requirements will be enforced, and what impact, if any, the regulation has had on these requirements.

A review of consumer injury and fatality data has shown that the increased use of HC products has been accompanied by an increase in the number of aerosol-related injuries, simultaneously, the decreasing use of CFC products has been accompanied by a decline in the rate of aerosol-related fatalities. An analysis of aerosol injuries indicates that the percent of injuries due to fires and explosions increased six-fold from 1975 to 1979, thus confirming allegations of the increased fire/explosion hazards of HCs. A review of aerosol-related fatalities has demonstrated that over 90 percent of these fatalities were "sudden sniffing deaths", the result of youngsters attempting to get high on the euphoria-inducing CFCs. The decline in these deaths in the period 1975 to 1979 parallels the decline in the use of CFC products. This study has been unable to separate the effects of regulation, public education, and changing drug abuse patterns on the decline in the fatality rate.

Chapter XIII

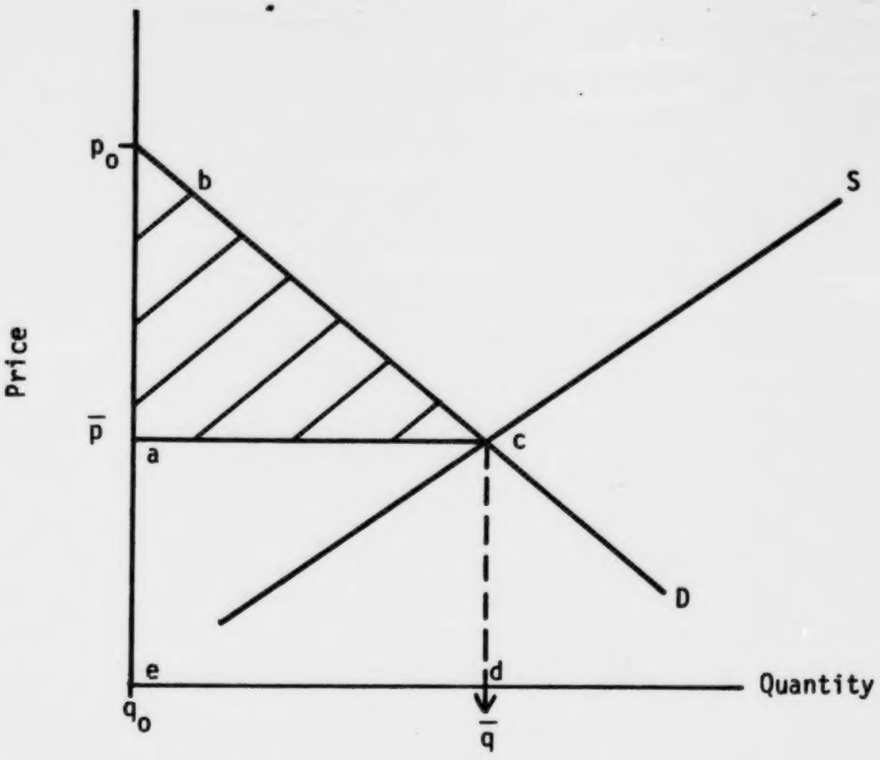
THE QUESTION OF CONSUMERS' SURPLUS

The total economic cost to society of government intervention can be defined as the resource cost to society plus the loss of consumers' surplus induced by the actions of the government. In Chapter VI, the resource cost to society of CFC aerosol regulations is estimated as the NPV of profit streams that would have been generated by the production equipment of CFC-related chemical and aerosol products. Since profit-type income was lost, the NNP of the U.S. economy was reduced. This decline is the resource cost of the ban to the U.S. economy; intermediate raw materials and labor that were displaced by regulation are assumed in this report to be transferable to other sectors and, hence, reemployed after regulation.

The reduction in consumers' surplus that occurred as a result of the ban is a social welfare loss that must be added to the resource costs of regulation to obtain the total economic costs to society. That there is some loss in consumers' surplus due to the ban follows from the fact that a product which consumers were able to purchase prior to the ban is no longer available; output of the banned product dropped from approximately 1.45 billion units in 1973 to almost zero by the end of 1978, as discussed in Chapter III. The NPV of the loss in the consumers' surplus, 1978 to 1990, can be estimated; for the case of CFCs, d'Arge [24] and Bailey [8,9] have each estimated the loss in consumers' surplus for aerosol and nonaerosol applications of CFCs.

The purpose of this chapter is to evaluate the possible size of the loss in consumers' surplus attributable to the ban on the use of CFCs as aerosol propellants. The discussion is necessarily somewhat technical.

The net loss in welfare to consumers of a ban is illustrated in Graph XIII-1. Assuming that prior to the ban demand is at $\overline{q}$ and price $\overline{p}$, consumers' surplus -- the difference between what consumers are willing and able to pay and the market price -- is defined as the area under the demand curve and above the price line, namely the area of the triangle, abc. Because of the ban, the product that was once available no longer is. Quantity, therefore, becomes zero or q_0, at price p_0, and the loss in consumers' surplus is the total area of the triangle abc.



Graph XIII-1. Loss in Consumers' Surplus Due to a Ban.

A loss in consumers' surplus [S(q)] should, in principle, be estimated in a general equilibrium framework as:

$$S(q) = -1/2\ \Sigma\, \Delta p_i\, \Delta q_i \tag{1}$$

where Δp_i = deviations in the prices of all goods that may have been affected by the ban including all substitutes and complements to the banned product

Δq_i = the resulting changes in quantities. This sum should also be taken over all affected goods, that is, not only CFC-propelled aerosol products but also over all of their substitutes and complements.*

In the case of CFC regulation, however, the prices of other goods in the economy -- including the prices of nonCFC-propelled aerosol products and nonaerosol products, both of which are close substitutes to CFC aerosol products -- seem to have remained unaffected by the ban. However, there are cases where new products have been introduced which may have generated additional consumer welfare. If we may ignore these new products, the above sum, $-1/2 \Sigma \Delta p_i \Delta q_i$, reduces to a single product and hence, $-1/2 \Delta p \Delta q$, where Δp and Δq are changes in the price and quantity, respectively, of CFC-propelled aerosol products. These changes were directly induced by the ban. In this partial equilibrium statement of the problem, then, the $\Delta p \Delta q$, captures only the direct effects on the banned product and not those on HC substitutes or on nonaerosol alternatives.

Changes in prices (Δp) cannot be estimated directly because Δp is the difference between the price that prevailed under the ban and the price that would have prevailed in the absence of the ban. But the ban on most products is total (CFC-propelled aerosol products are generally no longer produced) so that no price after the ban can be observed.

Changes in quantity (Δq) can be estimated. In Chapter V, hypothetical demand for individual products in the absence of regulation is estimated. The actual amount of CFC-propelled products consumed since the ban is relatively close to zero. One can, therefore, estimate the relevant Δq's using this information. Thus, to get around the difficulty of the lack of post-ban price information, the procedure is to estimate the demand function using data from the pre-ban period. One then assumes that the potential demand function after the ban is the same as the one estimated using the pre-ban data. Indirect estimates of Δp are obtained from the information on q's. This approach to the problem of estimating losses in consumers' surplus, which was also used by d'Arge and Bailey, can be explained in slightly more detail.

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*For a discussion of these propositions, see Hotelling [35] and Mishan [49] or Currie [23].

In particular, suppose that the demand function is linear, that is, it is of the form:

$$q = - a p + b \tag{2}$$

where q = the quantity of physical units of CFC aerosol products consumed per capita per year

p = the real price in 1976 dollars (i.e., the nominal price index of the CFC aerosol product deflated by a general price index, with 1976 as the base year)

a = a constant, determined by values of p and q

b = the sum of all terms not involving p.

Then it can be shown that the loss in consumers' surplus, S(q), is of the form:

$$S(q) = - \frac{1}{2} \left(\frac{1}{a} q_o^2 - \frac{2}{a} q_o \overline{q} + \frac{1}{a} \overline{q}^2\right) \tag{3}$$

where q_o = the quantity purchased under the ban

$\overline{q}$ = the quantity that would have been purchased in the absence of the ban.

Since q_o equals zero in the case of a ban, the above formula reduces to:

$$S(q) = - \frac{1}{2} \left(\frac{1}{a} \overline{q}^2\right) \tag{4}$$

This is the formula used by d'Arge and Bailey to estimate the loss in consumers' surplus due to CFC regulations.

The derivation of formula (3) and hence (4) is the following: solve (2) for price, so that

$$p = - \frac{1}{a} q + \frac{b}{a} \tag{a}$$

Consumers' surplus is:

$$S(q) = -\frac{1}{2}(\overline{q} - q_o)(p_o - \overline{p}) = -\frac{1}{2}(\overline{q} - q_o)[(-\frac{1}{a}q_o + \frac{b}{a}) - (-\frac{1}{a}\overline{q} + \frac{b}{a})] \quad (b)$$

$$S(q) = -\frac{1}{2}(\overline{q} - q_o)(-\frac{1}{a}q_o + \frac{1}{a}\overline{q}) \quad (c)$$

$$S(q) = -\frac{1}{2}[+\frac{1}{a}\overline{q}^2 - \frac{2}{a}\overline{q}\,q_o + \frac{1}{a}q_o^2] \quad (d)$$

When q_o equals zero (a ban), the second and third terms disappear and $S(q_o = 0) = -1/2\ (1/a\ \overline{q}^2)$. This is the Bailey formula [8,9].

Given formula (4), two questions are relevant to this study:

- Is the demand function (2) a reasonable approximation?
- If so, can the value of "a" be estimated reasonably accurately?

With respect to the form of the demand function in (2), two conclusions have been reached. First, (2) may be an acceptable approximation for a small variation in p and q around historically observed values of these variables before the ban, but such an estimate cannot be extended to the case where q actually becomes zero. This is a critical conclusion. With respect to the second question, a fairly extensive attempt has been made to estimate "a" for several variations of the demand function that were essentially of the form (2), using the data up to 1973. It was found that the estimate in the parameter "a" varies quite substantially depending on relatively minor variations in the specification of the form of (2). This finding is also of importance.

There are several reasons for this sensitivity to minor changes in the specification of the demand equation. It is partly because CFC aerosol products were still in an initial growth phase of the product during the sample period. Therefore, most of the variations in their sale are due to autonomous factors, partly because the historically observed variations in its price were not wide enough, and partly because the linear equation of the form (2) is not very satisfactory.

A standard linear specification of the demand for aerosols in the personal product category excluding shaving creams was chosen for estimation, where the objective was to obtain a plausible estimate of "a". An example of such an equation is:

$$q_A = a\ p_A + b\ p_N + c\ Y_{72\$} + DUM + d + e \qquad (5)$$

where q_A = the per capita demand for aerosols, in billions of units

p_A = the own real price of an aerosol

p_N = the real price of a substitute (usually a nonaerosol, but in principle, an HC-propelled aerosol)

$Y_{72\$}$ = real per capita disposable personal income

DUM = dummy for change in hairstyles in 1971

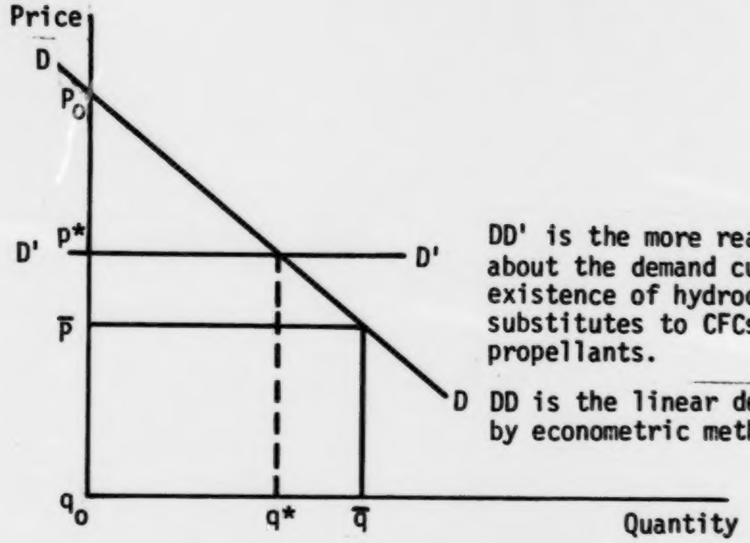
d = a constant term

e = an error term.

Thus, the demand for CFC-propelled aerosols depends upon their price, the price of substitutes for the banned product, real disposable income, and, in the case of the banned product, a dummy for the change in hairstyles. Of these variables, the "own" price term must have a negative sign, that is, the demand curve must slope downward for the result to be useful.

The estimate of "a" from various combinations of equation (5) -- a procedure also followed by d'Arge [24] and Bailey [8,9] -- varied between roughly the maximum of 140 to the minimum of 40. Since the quantity loss, $\Delta q = (\overline{q} - q_0)$, is roughly 8 aerosol units per capita, using formula (4) a loss of 8 units implies a loss of consumers' surplus of 23 cents to 80 cents per capita per year in 1976 dollars. Since population was 215 million persons in 1976, the total annual loss to society in consumers' surplus was between \$49 million and \$172 million per year, in 1976 dollars. (The smaller of these estimates is closer to the estimate of d'Arge and Bailey of the loss in consumers' surplus for aerosol application of CFCs.)

This range of \$49 to \$172 million per year, in 1976 dollars, in the loss of consumers' surplus is rather wide. It is our judgment that, in the presence of the close substitutes and assuming that the prices of these substitutes were not affected by the ban, the true loss of consumers' surplus is closer to the smaller limit of this range than to the larger limit, that is, about \$49 million per year, in 1976 dollars.



DD' is the more reasonable assumption about the demand curve, given the existence of hydrocarbons as close substitutes to CFCs as aerosol propellants.

DD is the linear demand curve estimated by econometric methods

Graph XIII-2. Demand for CFCs: Statistical Estimates "Versus" Hypothesis About HC Substitutes.

Given the availability of close substitutes, the actual loss in consumers' surplus could be even smaller because the demand for CFC-propelled products will become infinitely elastic at some price greater than $\overline{p}$ and significantly less than p_0. That is, it is probably impossible that price would have reached p_0 (where output = 0), because substitute propellants (chiefly HCs) would have replaced CFCs if the price of CFCs relative to HCs rose substantially. Thus, the most reasonable hypothesis about the demand curve is that demand would have become almost infinitely elastic at some quantity, q*, when price was p*. This possibility is illustrated in Graph XIII-2.

Thus, the conclusion is that the major economic cost to society of the ban on CFC-propelled aerosol products is the resource cost due to profit streams foregone, and not the loss in consumers' surplus. In addition, this report assumes no loss in resources due to jobs that were lost or raw materials not used, on the grounds they can be utilized elsewhere in the economy. To the extent the loss in consumers' surplus is greater than zero, equating the social cost of the ban to the resource cost means that the cost of the ban to society has been underestimated. That there has been some loss in consumer utility and hence in consumers' surplus follows from the facts of the ban and the fact that there are no perfect substitutes for the banned products.

Chapter XIV

COMPARISON OF THIS STUDY WITH THE IR&T REPORT

A secondary objective of this report is to compare the methods and results of this study with those of prospective studies that estimated the economic impact of regulating CFCs as aerosol propellants. Only one prospective study, the IR&T Report [36], provided numerical estimates of the economic impact of regulating CFC emissions on the aerosol industry.* This chapter therefore compares the methods and conclusions about economic impact in the IR&T report with those of this study. Only the methods and results are examined because there were no outside events that were unanticipated as of 1977, which could explain the difference in the two reports. These outside events include inflation, changes in consumer tastes not due to regulation, recession, or changes in the price or availability of substitute systems not induced by regulation.

SIMILARITIES

There are two similarities between the IR&T report and this report. One similarity is in the scope of inquiry, and the other similarity is reflected in the general direction of change in various measures of economic impact.

Scope

The impact on consumer prices is the primary measure of economic impact on consumers addressed in the IR&T report. The impact of regulation on the quantity of nonaerosol products is not explicitly considered. Because this study also examines changes in product quality, the scope of the economic impact on consumers is somewhat broader than IR&T's.

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*This does not deny the high quality of other prospective studies, such as the Commerce report [76]. This study has drawn heavily on the Commerce report for a number of items: the documentation that capital equipment is dedicated in various industrial sectors, which is a basis for driving the profit streams foregone out over time; data on employment in a base year; and a variety of other supplementary information on economic impact. Since the Commerce report did not estimate the size of the economic impact of regulating CFC aerosol uses, it is excluded from this discussion. For a review of five prospective studies, see Appendix E.

In the case of producers, both studies attempt to evaluate the economic impact of regulation on three industrial sectors:

- Marketers of aerosol products
- The aerosol sector (containers, valves, and fillers)
- The chemical sector (CFC manufacturers and feedstock chemicals that are precursors to CFCs).

This study also discusses warehousing, which is an increase in the scope of this report over the IR&T report.

Both studies examine the economic impact of regulation on employment, although the assumptions about reemployment differ. The studies also differ in their evaluation of the losses in social welfare due to regulation. This topic is not explicitly discussed in the IR&T report. Implicitly, by estimating the decline in value added due to regulation, IR&T evaluates the lost real resources to the U.S. economy. However, it does not consider the question of the loss in social welfare due to a loss in consumers' surplus.

Directions of Change

Table XIV-1 summarizes the direction of change in various measures of economic impact that are included in either the IR&T report or in this report. Generally, in cases where the two studies address the same issues, they find the same direction of change.

DIFFERENCES

There are four major differences between the IR&T report and this report:

- The distribution of impact
- The choice of measures of economic impact

Table XIV-1

COMPARISON OF THE IR&T REPORT AND THIS STUDY: SCOPE AND QUALITATIVE CONCLUSIONS

Scope	Qualitative Conclusions	
	IR&T	This Study
Consumers		
Prices	May be 15% less with HCs	? -- probably unaffected*
Product Quantity	Implies it will increase	Increased
Product Quality	NE	Declined
Producers		
Quantity	Temporary (4-year) decline	Declined
Profits	NE	Declined
Value Added	Temporary (4-year) decline	NE but implies a decline
Capacity Utilization	Will decline only in chemicals	Declined
Profit Margins on Sales	NE	Declined
Labor		
Employment	Will decline	Declined
Payroll	NE	Declined
Social Welfare		
Real Resources	Implies a decline	Declined
Consumers' Surplus	NE	Declined

*Costs of reformulation and of converting filling lines from CFCs to HCs seem to have canceled out the savings due to the fact that HCs are cheaper than CFCs.

NE = Not Estimated.

- The use of a discount rate
- The date for terminating economic impact.

The Distribution of Impact

Tables XIV-2 and XIV-3 summarize the numerical estimates of the economic impact of regulation on producers. Numerical estimates from the IR&T report are placed beside the numerical estimates of economic impact from this report. Care must be taken about drawing hasty conclusions from these tables, because the cost of regulation ($1.4 billion in 1976 dollars) appears to be the same in both studies (Table XIV-3). The comparison can be misleading for several reasons, one of which is that the two studies used different criteria (IR&T used value added and this study used profits) as measures of economic impact. Another misleading aspect of a gross comparison is that the distribution of economic impact among industrial sectors differs in the two reports. For example, in Table XIV-2, IR&T attributes 49 percent of the economic impact of regulation to lost value added by marketers. The results of this study suggest that most economic impact fell on fillers (62% of profit streams foregone). This study's approach to evaluating the economic impact on marketers is to estimate the costs of reformulation and the costs of converting filling lines. These costs have had an impact on profits, though of a once-and-for-all nature.

Measures of Economic Impact

The value added by a firm is its total sales minus the cost of goods or services it purchases from other firms; this is the measure of economic impact used by IR&T. Profits, the measure used in this study, are only one component of value added. Value added can be thought of as the contributions made to sales by two factors of production: labor and capital. These are costs to the firm that include:

- Total compensation of all employees (total payments made to labor, including all wages and salaries, all social security payments, all contributions to health or pension funds, and so forth)

Table XIV-2

COMPARISON OF THE IR&T REPORT AND THIS STUDY FOR ECONOMIC IMPACT ON PRODUCERS:* TWO MEASURES -- VALUE ADDED AND PROFITS

(Millions of 1976 Dollars)

Industrial Sector	IR&T Value Added Losses[a]	IR&T Percent, by Sector	This Study Profit Losses[b]	This Study Percent, by Sector
Marketers	696	49.2	NE	0.0
Aerosol Sector				
Containers	155	10.9	104.8	10.1
Valves	43	3.0	46.4	4.5
Fillers	142	10.0	638.1	61.5
Chemicals	380	26.8	248.9	24.0
Total	1,416	100.0	1,038.2	100.0

*IR&T does not apply a discount rate to its estimates of value added lost due to regulation, whereas this study does, namely 9.37% a year. If one uses a discount rate, the value added losses in IR&T are $1,109 million.

[a] Value added is the total sales of a company minus the costs of materials it purchases elsewhere. All data from IR&T are an unweighted average of its scenarios 5 and 6. This is the correct choice of scenarios, because it represents what happened both in terms of the length of time between the announcement of the ban and its taking effect, and also what happened in terms of alternative propellants that appeared on the market.

[b] Profits are profits before taxes that will have been lost due to regulation between 1975 and 1990. A rate of 9.37% is used to discount profit streams foregone due to regulation.

NE = Not Estimated. The approach to estimating economic impact on marketers was through costs. This is because nonaerosol sales seem to have offset aerosol sales for industry as a whole, albeit not for individual marketers. For a more complete discussion of these points, see Chapter VII of this report.

Table XIV-3

COMPARISON OF THE IR&T REPORT AND THIS STUDY FOR ECONOMIC IMPACT ON PRODUCERS:* THREE MEASURES -- VALUE ADDED, PROFITS, AND DIRECT COSTS

(Millions of 1976 Dollars)

Industrial Sector	IR&T Value Added Losses[a]	IR&T Percent, by Sector	This Study Profits and Direct Costs[b]	This Study Percent, by Sector
Marketers	696	49.2	403.0[c]	27.3
Aerosol Sector				
Containers	155	10.9	104.8	7.1
Valves	43	3.0	46.4	3.1
Fillers	142	10.0	670.8[d]	45.5
Chemicals	380	26.8	248.9	16.9
Total	1,416	100.0	1,473.9	100.0

*IR&T does not apply a discount rate to its estimates of value added lost due to regulation, whereas this study does, namely 9.37% a year. If one uses a discount rate, the value added losses in IR&T are $1,109 million.

[a] Value added is the total sales of a company minus the costs of materials it purchases elsewhere. All data from IR&T are an unweighted average of its scenarios 5 and 6. This is the correct choice of scenarios, because it represents what happened both in terms of the length of time between the announcement of the ban and its taking effect and also what happened in terms of alternative propellants that appeared on the market.

[b] Several measures of economic impact were used in this study. As the data in Table XIV-2 shows, primary emphasis was placed on estimating economic impact for the chemical and aerosol sectors by estimating discounted profit streams foregone between 1975 and 1990, in millions of 1976 dollars. Additional cost information is included in this table for marketers and for fillers. See footnotes c and d.

[c] In the case of marketers, the quantifiable costs of regulation are the costs of reformulation ($337 million, 1976 dollars) and the costs of converting some filling lines ($66 million, 1976 dollars).

[d] In the case of fillers, quantifiable impact is the sum of profit streams foregone due to quantity losses ($638.1 million, 1976 dollars) and the costs of converting some filling lines ($32.7 million, 1976 dollars).

- The cost of capital, including capital consumption allowances (this is an allowance for equipment depreciation, the former term is used when certain criterion for consistency over firms in collecting data is desired), interest payments, and profits -- both distributed and retained.

Annual capital costs (or value added by capital) may be summarized by the following equation:

$$\begin{aligned} pQ - mM &= VA \\ &= wL + R \end{aligned}$$

where p = average price of the product sold
Q = quantity sold
m = average price of materials bought from other firms
M = average quantity of materials bought from other firms
VA = value added
w = wage rate (including all items of compensation)
L = total quantity of labor
R = residual income, including interest income, depreciation allowances (adjusted for consistency among firms), and profit-type income -- retained or given to stockholders.*

To illustrate potential orders of magnitude in the difference between using value added and profits as the measure of impact, data has been taken from the national income and products accounts (NIPA) of the U.S. in 1976. From Table XIV-4, it can be seen that for all corporations, on average, only 13.2 percent of value added in 1976 is attributable to profits before taxes.

One cannot apply these percents directly to the IR&T estimates. That is, one cannot say that IR&T estimates of profit impacts are 13.2 percent of $1.4 billion, or $185 million, in 1976 dollars. A numerical estimate of how much lower IR&T's impact would have been with a profits criterion cannot be

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*Whether costs of labor or of capital are taken as the "residual" in actual calculations depends on the form in which data is available.

Table XIV-4

VALUE ADDED BY ALL U.S. CORPORATIONS

Value Added Components	Billions of 1976 Dollars	% of Total
Value Added by all U.S. Corporations[a]	988.0	100.0
Capital Consumption Allowances	106.8	10.8
Indirect Business Taxes	99.8	10.1
Compensation of Employees	650.2	65.8
Profits Before Tax	130.0	13.2
Other Components	NE	0.1

[a] Gross domestic product of nonfinancial corporate business.

NE = Not Estimated.

Source: CEA, Economic Report of the President [75, p. 216].

evaluated because of problems in tracing the assumptions about the components of value added in the IR&T report.

The Appropriate Measure of Economic Impact. Profits lost due to regulations is a more appropriate measure of economic impact than value added. The use of value added assumes that labor as well as capital became unemployed due to regulation and that the displaced labor could not be reemployed elsewhere in the economy. This assumption is counter-intuitive; a more reasonable assumption is that existing capital cannot be reemployed and that labor can.

For labor, the plausible assumptions are:

- Most of the workers who were unemployed due to regulation have been reemployed elsewhere, and have not permanently withdrawn from the labor force.
- For those who were reemployed, some remained with the same firm in similar jobs and did not incur any costs associated with job searches. Others had to move (either geographically or from one employer to another), and in the process, may have had to absorb the costs of this transition. Some may have been forced to accept a lower wage than they would have earned in the absence of regulation.

Since IR&T implicitly assumes both labor and capital were permanently unemployed due to regulation, it appears to have overestimated economic impact within the four years it addresses. IR&T provides neither the appropriate quantity estimates nor a breakdown of value added into all its components; consequently, one cannot calculate profit impacts in order to compare the two reports.

The Use of a Discount Rate

The IR&T report does not discount its value added losses due to regulation in order to reflect the time profile of economic impact. This procedure is incorrect. The effect of applying the discount rate of 9.37 percent used in this study to the IR&T results can be calculated. The year-by-year results are in Table XIV-5.

Table XIV-5

DISCOUNTING ANNUAL ECONOMIC IMPACT IN THE IR&T REPORT

Year	Scenario 5-1/2	Discounted to 1976 @ 9.37%
1977	189.7	173.4
1978	362.4	303.0
1979	435.9	333.2
1980	428.9	299.8
Total	1,416.9	1,109.4

The Date for Terminating Economic Impact

This report differs from IR&T in its conclusions about the termination date of economic impact. IR&T assumed that the economic impact on consumers and producers would become zero by 1981. This study finds that impact will continue at least until 1990. Even the choice of 1990 as a date for terminating economic impact requires close scrutiny.

The decision by IR&T to terminate economic impact due to regulation by 1981 is not explained in the report; moreover, this study concludes that it was an inappropriate assumption to make because of facts relating to capital equipment in the aerosol and chemical sectors. Specifically, capital equipment in the aerosol and chemical sectors became unemployed due to regulation (this equipment was largely dedicated to aerosol or CFC production); moreover, it had a remaining economic life of at least 15 to 20 years. Thus, 1990 becomes the earliest reasonable date on which to terminate the economic impact of regulation. This finding is supported by published reports (the Commerce Report and Wolf) and also by discussions with members of industry.

Secondly, impact is continuing because there has been no change in consumer tastes with respect to aerosols. If IR&T had any basis for believing consumer tastes with respect to aerosols would return to their preregulation level by 1981, it did not say so. The finding of this study is that there was no basis for believing that consumer tastes will change until 1985. Even this assumption of changes in consumer tastes in 1985 may be unduly optimistic.

And thirdly, a short-lived economic impact is clearly an inappropriate assumption in the case of CFC manufacturers since output of CFCs for aerosol use dropped from 520 million pounds in 1973 to only 21 million pounds per year by 1979. This, combined with facts about the remaining economic life of that equipment in the chemical and aerosol sectors, makes 1981 an unreasonable date on which to terminate economic impact.

The overall conclusions of this study with respect to the IR&T report are that IR&T did not address at least two critical issues affecting economic impact and did not use the more appropriate measure of economic impact. Specifically, IR&T explicitly addressed neither the issues of capital nor consumer tastes, and thus concluded a short-term impact. IR&T also did not explicitly discuss why value added was chosen as a measure of economic impact. IR&T's criterion makes an unreasonable assumption about displaced workers.

This study finds the decision about the termination date for economic impact to be the major analytic shortcoming of the IR&T report. The decision to terminate impact in 1981 had a substantial effect on the duration and, therefore, the size of the IR&T economic impact calculations.

APPENDICES

Appendix A

PRICE INDEXES

The intent of Appendix A is to provide supplementary information on the use and construction of the price indexes in this study.

BLS Wholesale Price Indexes

BLS [89] collects monthly wholesale price information on a wide variety of products. To the extent that BLS prices a product, BLS indexes have been used in this study. Table A-1 summarizes some of the products for which data relevant to this study are available from BLS. It is important to know exactly what BLS is pricing for any given product because BLS sometimes tracks price behavior for an individual brand (unidentified, of course) and sometimes the average price paid for a group of manufacturing products. BLS occasionally uses a "spot price", although generally it does not.

The specifications ("specs") for any product are available upon request from BLS. Since not everyone is familiar with them, two specs that relate to this project are included. One is for CFC-11. The other is for an aerosol fragrance.

For CFC-11 (BLS Code: 0614-0382), the documentation is:

> "Trichlorofluoromethane (Fluorocarbon 11), refrigerant, bulk quantities, realized net price, one month lag, chemical manufacturing to manufacturing, F.O.B. plant or shipping point, or delivered."

For aerosol toilet water or cologne (BLS Code: 0675-0101), the documentation is:

> "Toilet water or cologne, aerosol, manufacturer, or distributor to retailer, F.O.B. New York or warehouse or freight prepaid."

Table A-1

SELECTED INDEXES OF WHOLESALE PRICES

Product	No. in BLS Classification Code*
Chemicals**	
CFC-11	06-14-0382.05
CFC-12	06-14-0331.03
Carbon tetrachloride	06-14-03-24
Carbon disulfide	06-14-03-21
Hydrofluoric acid	06-13-02-22
Personal Products	
Nonaerosol shaving cream	06-75-0181.02
Nonaerosol deodorant	06-75-01-54.01
Aerosol hairspray***	06-75-01-13
Aerosol toilet water or cologne	06-75-01-01.11
Nonaerosol perfume	06-75-01-04.01

*BLS has historically collected and classified data with its own classification code, not the SIC code. It now publishes price information on both bases, but there is generally a greater wealth of product detail in the "older" BLS code.

**This list is not exhaustive; some indexes of wholesale prices of affected products were not required for this study.

***A price index for aerosol hairsprays was only collected for a short period of time and therefore cannot be used in this study.

Source: BLS [89].

Wholesale Price Indexes

Wholesale price indexes were constructed for those cases in which data were not available from BLS and for which indexes were needed for the purposes of this study. The indexes enter two parts of this report: the evaluation of the impact of regulation on consumer prices, and the estimates of demand in the absence of regulation, 1960 to 1979.

Procedures. The procedures for constructing these indexes were similar to the procedures used by BLS. The source of published information about the suggested wholesale prices of consumer products annually, from 1960 to 1979, is either the Redbook [45] or the Bluebook [2] for pharmacists. Because of the importance of conclusions about prices of aerosol hairsprays and aerosol antiperspirants, each index used information for four major brands. The following steps were taken in the construction of price indexes for this report:

- "Major" brands in each product category were identified. A variety of lists were used for this purpose, including an old survey by DuPont* [27,28], a recent survey by Parents Magazine** [60], and scattered information from marketers and local grocery stores. The Census definition of a major product -- that a company's value of shipments in a given product category is $100,000 or more in any year -- comes closest to that used.
- Annual suggested wholesale prices were then collected from 1960 to 1980, for any major brand for which there was (a) a suggested wholesale price published in the Redbook/Bluebook, and (b) a nonaerosol as well as an aerosol price.***
- Each price series was indexed so that 1967 = 100, in order to conform to BLS procedures.

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*Not provided by DuPont.

**Provided by Parents Magazine.

***To the best of our knowledge, there is no price for a nonaerosol hairspray prior to regulation in the Redbook/Bluebook.

- In cases where products (i.e., hairsprays and A/D) were reformulated from CFCs to HCs due to regulation, an "equivalency" in usage per aerosol unit was made. For an explanation of why hairsprays and A/D were selected, see Chapter III. "Equivalency" in this case is not simply a matter of considering the differences in densities between CFCs and HCs. One must also take into account other components used as a result of reformulating the propellants, for example, different amounts of resins are required in aerosol hairsprays (or aluminum salts for antiperspirants) using HCs instead of CFCs. In addition to this problem, information on equivalency by brand is proprietary; therefore, no adjustment could be made for a particular brand. However, in the absence of brand-specific information some judgments were made about the general equivalency between CFC- and HC-propelled aerosol products, and these are in Table A-2.
- After hairsprays and A/D adjustments were made, the price series was reindexed for hairsprays and A/D (1967 = 100). To illustrate the sensitivity of the conclusions of these adjustments, two sets of results can be prepared: the adjusted price index (for equivalency) and the unadjusted price index.

Table A-2

EQUIVALENCY ASSUMPTIONS

Product	CFCs	HCs	Equivalency
Hairsprays	13 oz.	8-9 oz.	.654
Antiperspirants	8 oz.	3-4 oz.	.438

Source: Industry.

The Results and Their Reliability. Using the procedures outlined in the previous section, price indexes were constructed for the following aerosol and nonaerosol products: (a) hairsprays,* (b) antiperspirants,** (c) shaving creams, (d) nonexempt pharmaceuticals, (e) insecticides, and (f) various household products (waxes, spray starches, and room deodorants/disinfectants). The following points are noted:

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*Data for nonaerosol hairsprays are unavailable prior to the announcement of the ozone depletion hypothesis.

**Antiperspirant data were used, rather than deodorant data, because about 80 percent of products sold in the Seventies were antiperspirants. The series was "spliced" in the sense that deodorant data form the basis of some of the pre-1970 observations.

- It is possible to construct a continuous time series for these products, based on their suggested wholesale prices from 1960 to 1980. Data are annual.
- On the basis of this, it is possible to construct:
  - A nominal price index of some aerosol and nonaerosol products, 1960 to 1980
  - A real price index of some aerosol products, defined as the nominal price index divided by the wholesale price index, 1960 to 1980.
  - A relative price index, defined as the nominal price index of an aerosol divided by the nominal price index of a nonaerosol product, 1960 to 1980.*
- The time series of price indexes for hairsprays and antiperspirants adjusted for equivalency before and after reformulation must be viewed critically since:
  - Nonbrand-specific information about equivalency is applied to particular brands.
    - The four brands for which price indexes are constructed do not exhibit uniformity in price behavior before and after reformulation (some rose, some fell, and some remained constant).
    - There is no way to evaluate which of these four time series, if any, is "correct".
  - Discounted wholesale and retail prices are often used.

Consumer Price Indexes

One could construct indexes of consumer prices, by product, using the same sources and procedures described above. That is, one takes the suggested retail price of brands from the Redbook/Bluebook of pharmacists and indexes these so that 1967 = 100.

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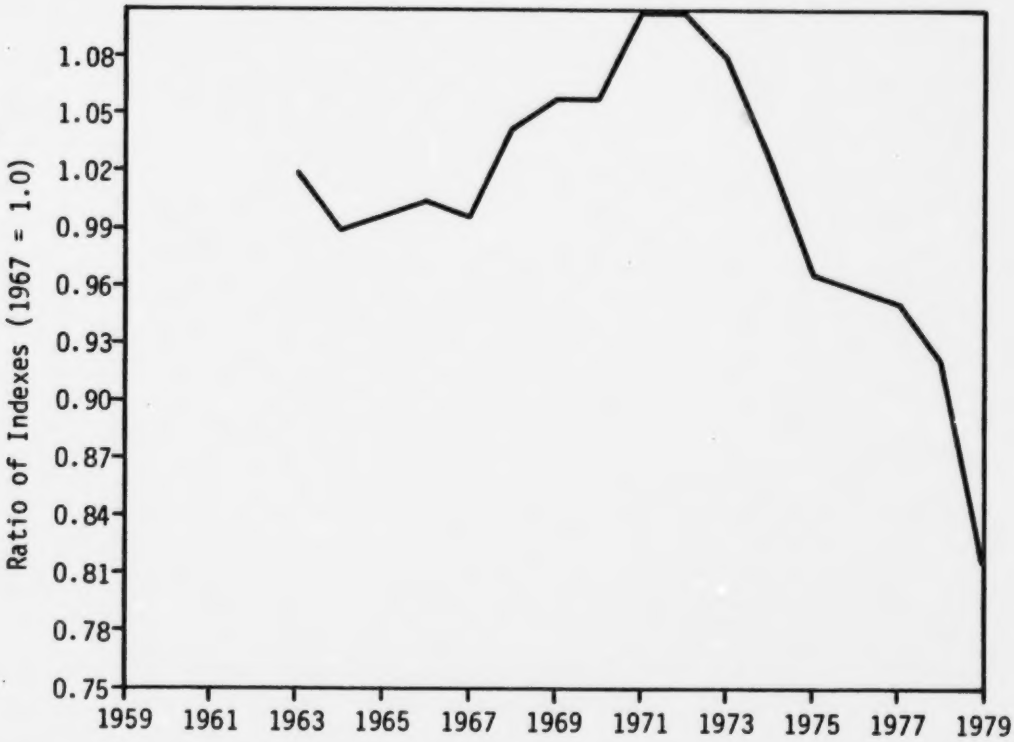
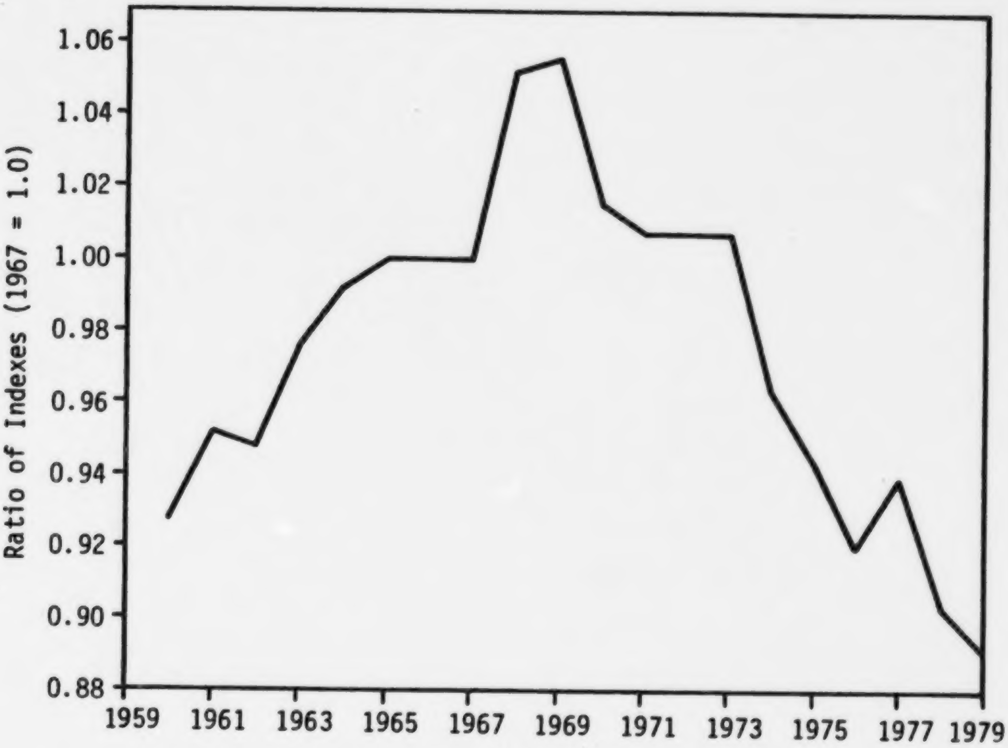
*Graphs of the real and relative prices for some products other than hairsprays and antiperspirants are at the end of this Appendix.

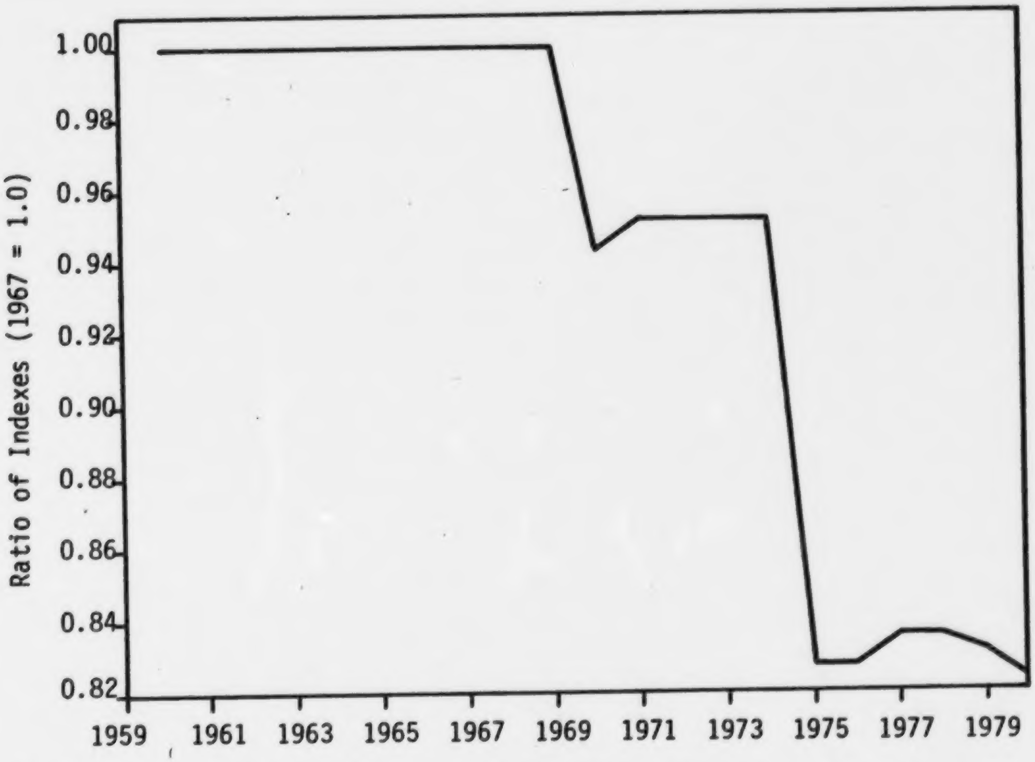
This method results in a misallocation of resources for the following reasons: one, discounting of products is reportedly so widespread that a suggested retail price is virtually meaningless; the second, more important reason is that the results would parallel those for wholesale prices. A scanning of some of the numbers involved indicates that the suggested retail price is highly (though not perfectly) correlated with the suggested wholesale price. This means the price indexes would be virtually identical. Thus, the decision was made to use the wholesale price indexes for the purposes of estimating the economic impact of regulation on producers and also the impact on consumers.



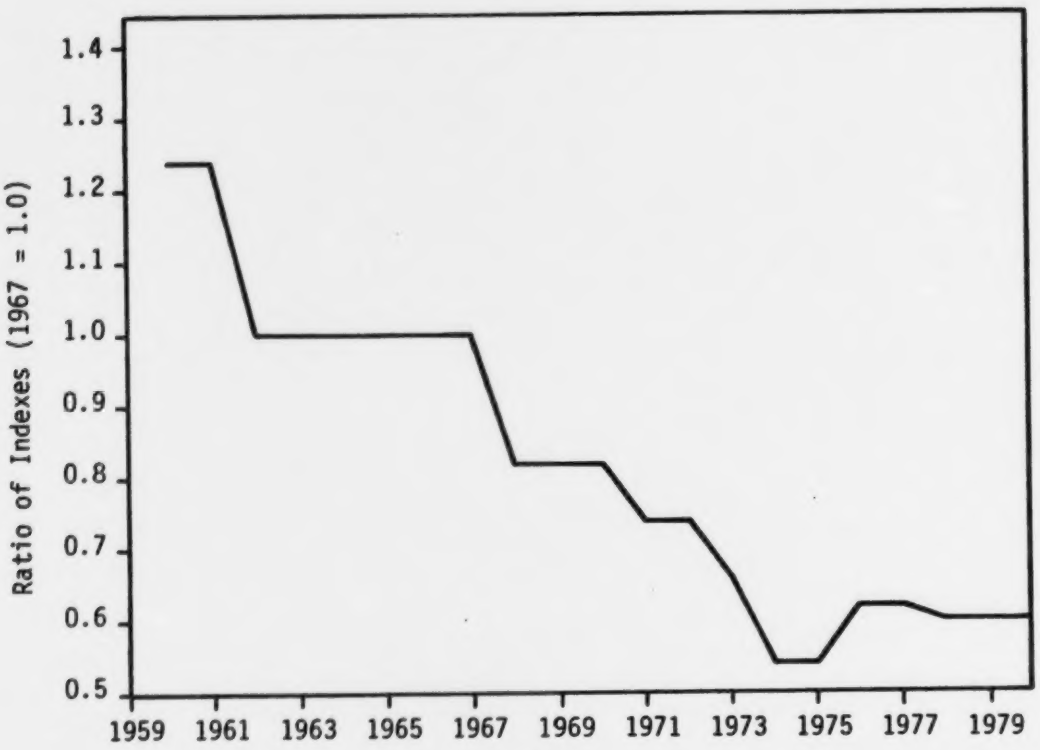
Graph A-1. The Price of an Aerosol Cologne Relative to a Nonaerosol Cologne (PAC/PNC).



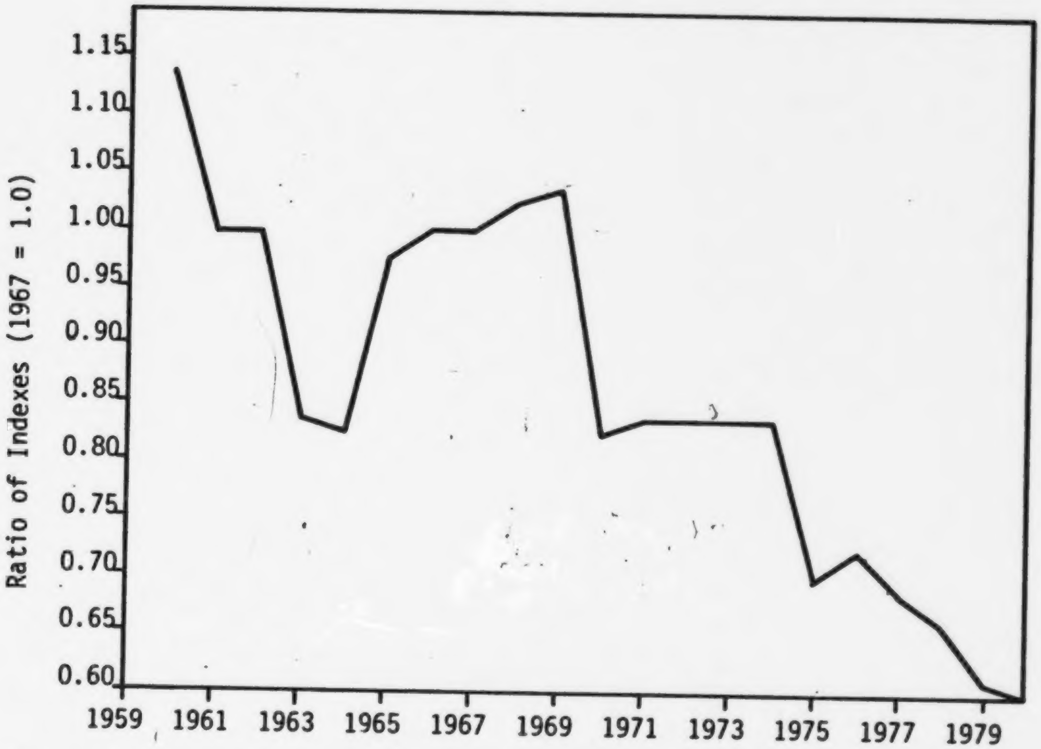
Graph A-2. The Price of an Aerosol Shaving Cream Relative to a Nonaerosol Shaving Cream (PASC/PNSC).



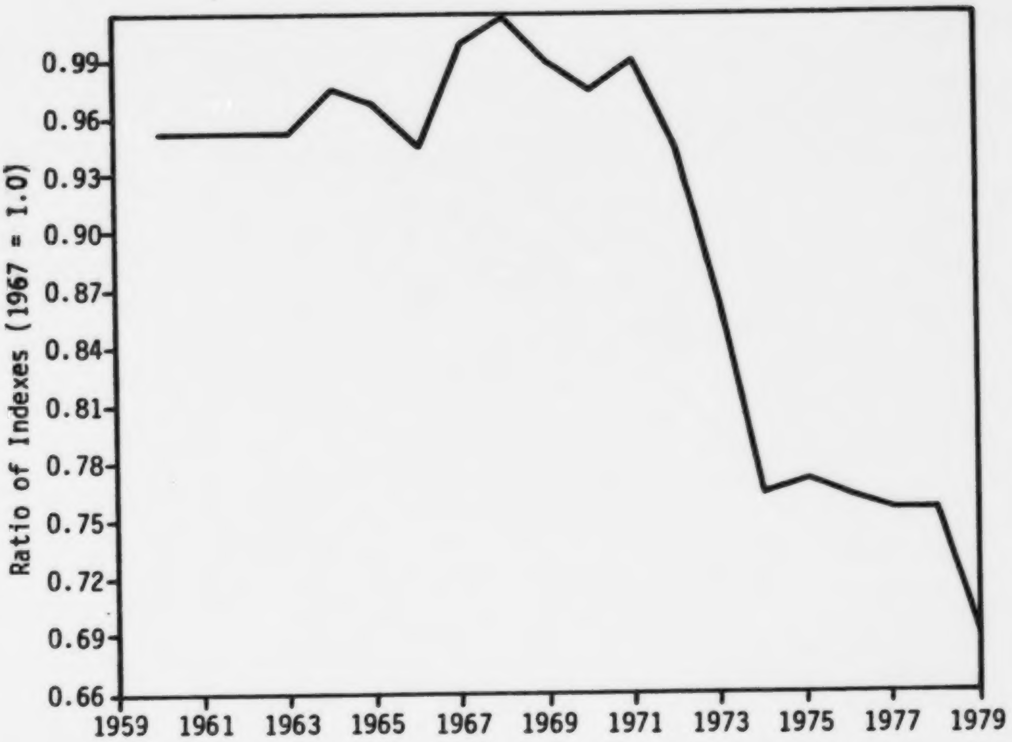
Graph A-3. The Price of an Aerosol Household Product Relative to a Nonaerosol Household Product (PAHH/PNHH).



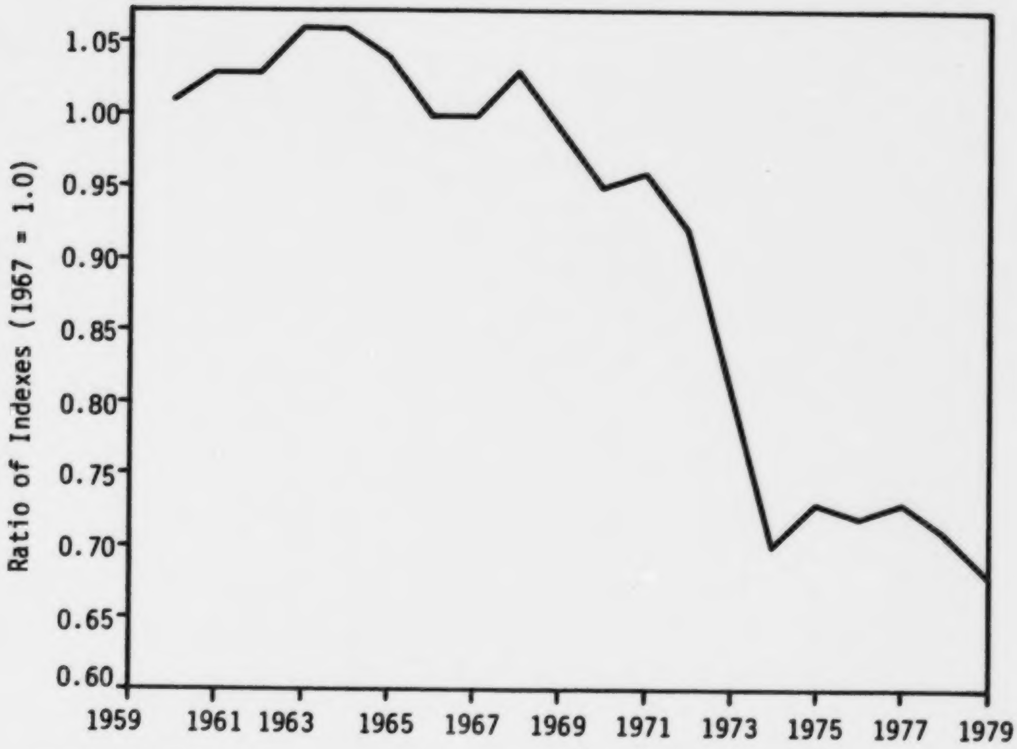
Graph A-4. The Price of an Aerosol Insect Repellant Relative to a Nonaerosol Insect Repellant (PAI/PNI).



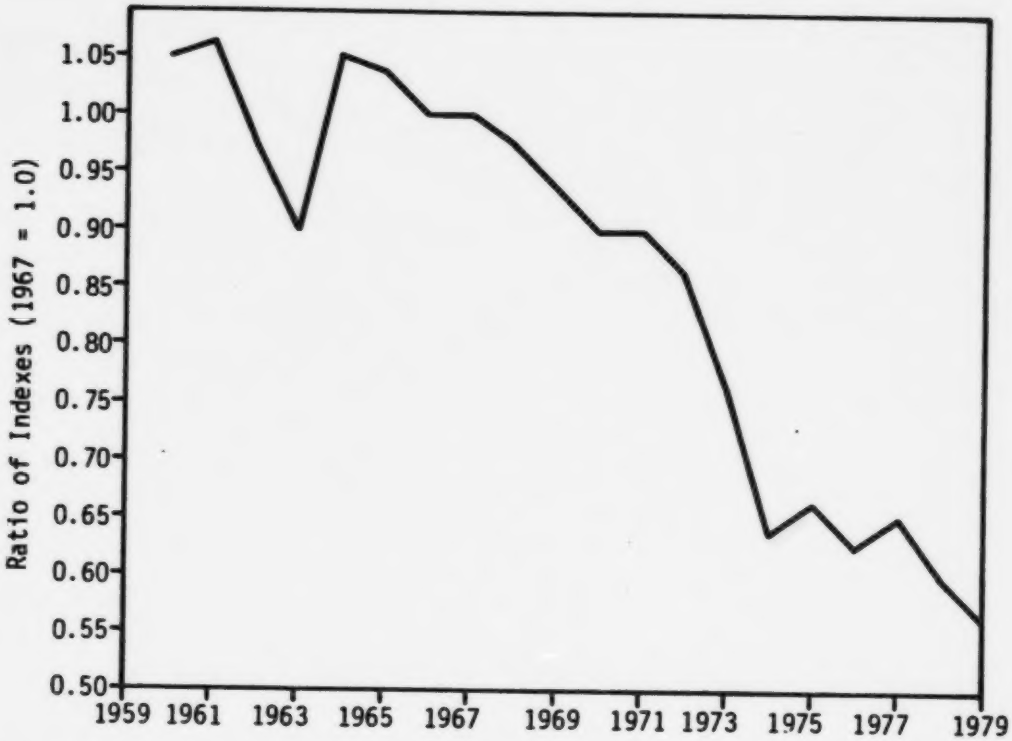
Graph A-5. The Price of an Aerosol Pharmaceutical Relative to a Nonaerosol Pharmaceutical (PAPH/PNPH).



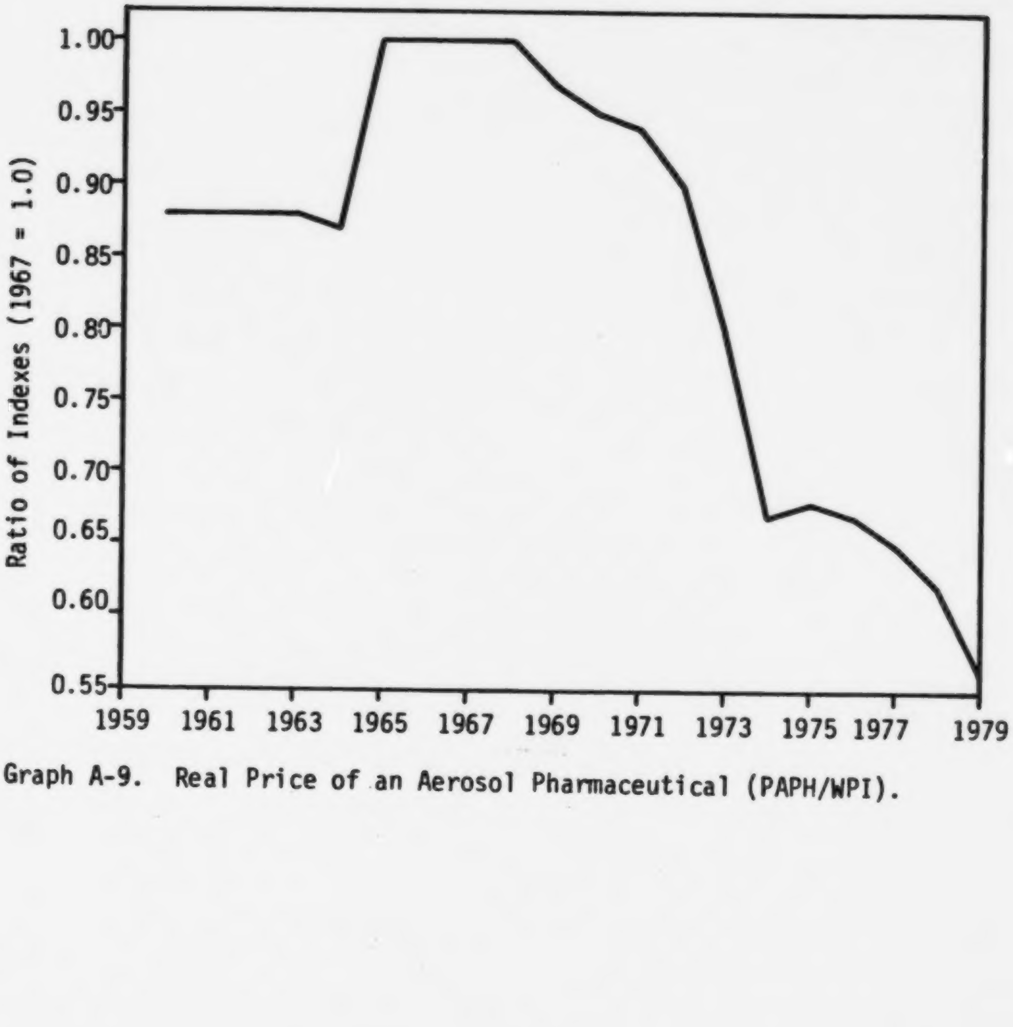
Graph A-6. Real Price of an Aerosol Cologne (PAC/WPI).



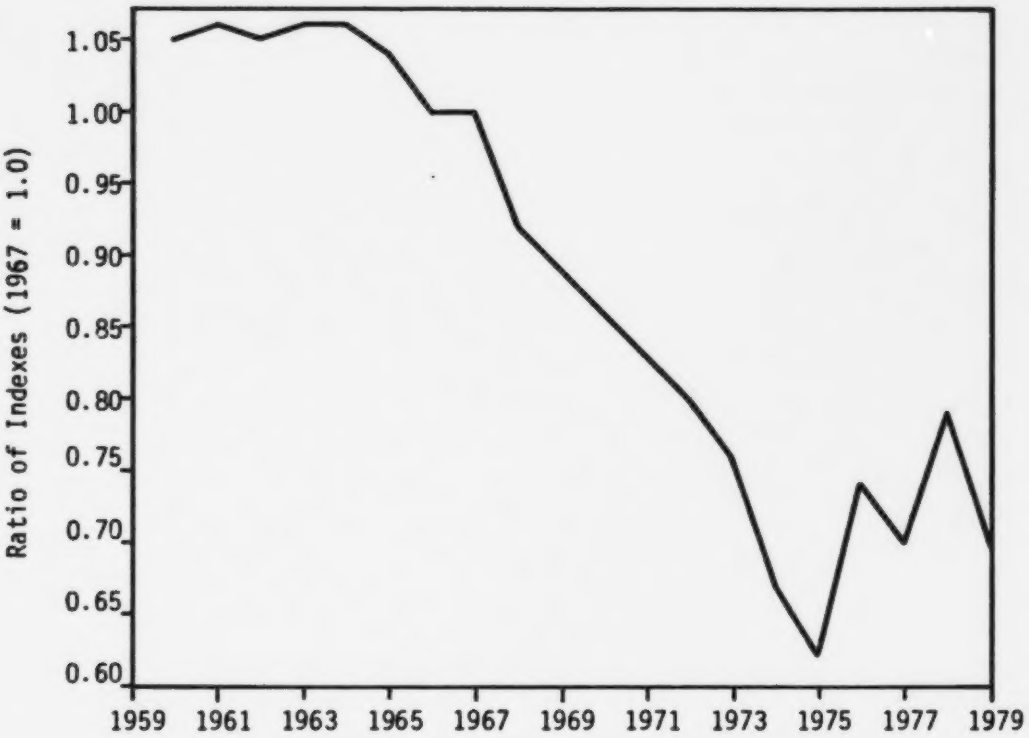
Graph A-7. Real Price of an Aerosol Shaving Cream (PASC/WPI).



Graph A-8. Real Price of an Aerosol Household Product (PAHH/WPI).



Graph A-9. Real Price of an Aerosol Pharmaceutical (PAPH/WPI).



Graph A-10. Real Price of an Aerosol Insect Repellant (PAI/WPI).

Appendix B

STATISTICAL RESULTS

Appendix B contains four sets of information. They are:

- Aerosol products for which demand is estimated.
- The data bank for the variables in the equations.
- The equations used in making the statistical estimates of demand in the absence of regulation, 1960 to 1974, by product categories. In this part of the Appendix, the usual statistical information (R^2, t statistics, DW) is included. In addition, the results of the Chow test of homogeneity* are given for the same specification of equations for the period 1960 through 1979, compared with those for 1960 to 1974.
- Graphs of the difference between the actual values of demand and those predicted by the equations (based on information from 1960 to 1974) for the forecast period: 1975 through 1979. In cases where adjustments were made in the predicted values to conform with outside information, both what was done and why are described in Chapter V of the report.

These results are only one part of the evaluation of effects of regulation and are best understood in the context of the entire report. A discussion of the use of these statistical results in the report is in Chapter V.

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*For a general discussion of tests of homogeneity, see Kmenta [42]. For the use of the Chow test in this case, see Johnston [40] or Chow [19].

Table B-I

AEROSOL PRODUCTS FOR WHICH DEMAND IS ESTIMATED

Equation Number	Title
I.	Personal Products (QAPP)
A.	Antiperspirants/Deodorants (QADA)
B.	Hairsprays (QAHS)
C.	Colognes (QAC)
D.	Shaving Creams (QASC)
E.	Residual (QAPPR)
II.	Household Products (QAHH)
A.	Household Wax (QAHW)
B.	Household Room Deodorants/Disinfectants (QAHD)
C.	Household Laundry Products, including Spray Starch (QAHS)
D.	Other Household Products (QAHR)
III.	Veterinary Products (QAV)
IV.	Pharmaceutical Products (QAPH)
V.	Paints (QAP)
VI.	Insecticides (QAI)
VII.	Industrial Products (QAIN)
VIII.	Food (QAF)
IX.	Automotive Products (QAA)
X.	Total Demand (QAT)

Table B-II

VARIABLES IN THE DATA BANK* USED FOR DEMAND EQUATIONS

Variable	Length of Series From-To	Description	Units	Sources
DUM	1960-1979	A dummy for the change in women's hairstyles	0 from 1960 to 1970; 1 from 1971 to 1974; 0 thereafter	Transformation
IND	1960-1979	Index of Industrial Production	1967=100	Statistical abstract
MILE	1960-1979	Miles travelled per year	billions of passenger-miles	Statistical abstract
PAC	1960-1979	Index of the price of aerosol colognes	1967=100	BLS
PADA	1960-1979	Index of the price of aerosol A/D	1967=100	Redbook and transformation
PAH	1960-1979	Index of the price of aerosol hairsprays	1967=100	Redbook and transformation
PAHH	1960-1979	Index of the price of aerosol household products	1967=100	Redbook and transformation
PAI	1960-1979	Index of the price of aerosol insecticides	1967=100	Redbook and transformation
PAPH	1960-1979	Index of the price of aerosol pharmaceuticals	1967=100	Redbook and transformation
PAPP	1960-1979	Index of the price of personal products	1967=100	Transformation

(Continued)

Table B-II

(Continued)

Variable	Length of Series From-To	Description	Units	Sources
PASC	1960-1979	Index of the price of aerosol shaving creams	1967=100	Redbook and transformation
PNC	1960-1979	Index of the price of nonaerosol colognes	1967=100	BLS
PNDA	1960-1979	Index of the price of nonaerosol A/D	1967=100	BLS
PNHH	1960-1979	Index of the price of nonaerosol household products	1967=100	Transformation
PNI	1960-1979	Index of the price of nonaerosol insecticides	1967=100	Redbook and transformation
PNPH	1960-1979	Index of the price of nonaerosol pharmaceuticals	1967=100	Redbook and transformation
PNPP	1960-1979	Index of the price of nonaerosol personal products	1967=100	Transformation
PNSC	1960-1979	Index of the price of nonaerosol shaving creams	1967=100	BLS
POP	1959-1979	Estimated population of the U.S.	Millions of Persons	Census
QAA	1960-1979	Quantity of aerosol automotive products filled	Millions of Units Filled	CSMA
QAC	1960-1979	Quantity of aerosol colognes (fragrances) filled	Millions of Units Filled	CSMA and transformation
QADA	1960-1979	Quantity of aerosol A/D filled	Millions of Units Filled	CSMA and transformation
QAF	1960-1979	Quantity of aerosol food products filled	Millions of Units Filled	CSMA

(Continued)

Table B-II

(Continued)

Variable	Length of Series From-To	Description	Units	Sources
QAH	1960-1979	Quantity of aerosol hairsprays filled	Millions of Units filled	CSMA and transformation
QAHD	1960-1979	Quantity of aerosol room deodorants/disinfectants filled	Millions of Units Filled	CSMA and transformation
QAHH	1960-1979	Quantity of aerosol household products filled	Millions of Units Filled	CSMA
QAHS	1960-1979	Quantity of aerosol household laundry products including starches filled	Millions of Units Filled	CSMA and transformation
QAHW	1960-1979	Quantity of aerosol household waxes filled	Millions of Units Filled	CSMA and transformation
QAI	1960-1979	Quantity of aerosol aerosol insect sprays filled	Millions of Units Filled	CSMA
QAIN	1960-1979	Quantity of aerosol industrial products filled	Millions of Units Filled	CSMA
QAP	1960-1979	Quantity of aerosol paint products filled	Millions of Units Filled	CSMA
QAPH	1960-1979	Quantity of aerosol pharmaceutical products filled	Millions of Units Filled	CSMA and transformation
QAPP	1960-1979	Quantity of aerosol personal products filled	Millions of Units Filled	CSMA
QAPPR	1960-1979	The quantity of residual aerosol personal products filled QAPPR = [(QAPP) - (QADA + QASC + QAH + QAC)]	Millions of Units Filled	Transformation

(Continued)

Table B-II

(Continued)

Variable	Length of Series From-To	Description	Units	Sources
QASC	1960-1979	Quantity of aerosol shaving creams filled	Millions of Units Filled	CSMA and transformation
QAT	1960-1979	Total quantity of aerosol products filled	Millions of Units Filled	CSMA
QATI	1960-1979	Adjusted total of all aerosol products filled (QAI + QAV + QAA + QAIN + QAHH + QAP + QAF + QAPP) where QAPP = (QADA + QASC + QAH + QAC + QAPPR)	Millions of Units Filled	Transformation
QAV	1960-1979	Quantity of aerosol veterinary products filled	Millions of Units Filled	CSMA
WPI	1960-1979	Wholesale price index (producer price index)	1967=100	BLS
Y	1959-1979	Real disposable income	Billions of 1972 Dollars	BEA
YPC	1959-1979	Real disposable income per capita in the U.S.	1972 Dollars	CEA

*Sources: BLS [87], with an explanation in Appendix A; the Redbook and Bluebook of pharmacists [45,2], with an explanation of any transformations in Appendix A; CSMA [17], with a discussion in Johnsen [37,38], as well as in the text; Census [80]; and BEA and CEA [75,77,78].

Table B-III

EQUATIONS FOR ESTIMATING PER CAPITA DEMAND FOR AEROSOLS

1960 TO 1974 AND 1960 TO 1979*

Equation Number	
I. Personal Products	1) $\ln(\mathrm{QAPP/POP}) = \underset{(-9.6192)}{-28.1659} - \underset{(-2.5998)}{1.7136} \ln(\mathrm{PAPP/PNPP}) + \underset{(4.1952)}{0.9393} \ln(\mathrm{PAPP/WPI}) + \underset{(10.1935)}{3.6639} \ln(\mathrm{YPC})$ $n = 15$ $\quad \overline{R}^2 = 0.9671$ $\quad SSE = 0.0235$ $\quad DW = 1.8048$ 2) $\ln(\mathrm{QAPP/POP}) = \underset{(-1.8363)}{-13.0499} + \underset{(4.2729)}{3.5972} \ln(\mathrm{PAPP/PNPP}) + \underset{(1.3188)}{0.7518} \ln(\mathrm{PAPP/WPI}) + \underset{(2.0771)}{1.8155} \ln(\mathrm{YPC})$ $n = 20$ $\quad \overline{R}^2 = 0.7055$ $\quad SSE = 0.3682$ $\quad DW = 1.3015$ Chow Test: $F = 23.45$
I.A A/D	1) $\ln(\mathrm{QADA/POP}) = \underset{(-12.3926)}{-40.1608} - \underset{(-4.2120)}{1.2909} \ln(\mathrm{PADA/PNDA}) + \underset{(0.1716)}{0.0591} \ln(\mathrm{PADA/WPI}) + \underset{(12.4164)}{4.9736} \ln(\mathrm{YPC})$ $n = 15$ $\quad \overline{R}^2 = 0.9855$ $\quad SSE = 0.1091$ $\quad DW = 1.7631$ 2) $\ln(\mathrm{QADA/POP}) = \underset{(-4.5755)}{-49.9011} + \underset{(0.0410)}{0.0460} \ln(\mathrm{PADA/PNDA}) + \underset{(2.5640)}{2.1620} \ln(\mathrm{PADA/WPI}) + \underset{(4.5767)}{6.1731} \ln(\mathrm{YPC})$ $n = 20$ $\quad \overline{R}^2 = 0.7150$ $\quad SSE = 2.3761$ $\quad DW = 0.6372$ Chow Test: $F = 45.71$
I.B. Hairsprays	1) $\ln(\mathrm{QAH/POP}) = \underset{(-8.2723)}{-33.3649} - \underset{(-5.1467)}{0.2107} (\mathrm{DUM}) + \underset{(8.4105)}{4.2181} \ln(\mathrm{YPC})$ $n = 15$ $\quad \overline{R}^2 = 0.8618$ $\quad SSE = 0.3315$ $\quad DW = 1.6006$ 2) $\ln(\mathrm{QAH/POP}) = \underset{(-4.1156)}{-28.4860} - \underset{(-4.4426)}{0.2768} (\mathrm{DUM}) + \underset{(4.2010)}{3.6157} \ln(\mathrm{YPC})$ $n = 20$ $\quad \overline{R}^2 = 0.5420$ $\quad SSE = 1.4979$ $\quad DW = 0.5126$ Chow Test: $F = 8.42$

(Continued)

Table B-III

(Continued)

Equation Number	
I.C Colognes	1) $\ln(QAC/POP) = \underset{(-4.9675)}{-35.1840} - \underset{(-1.0147)}{2.2022} \ln(PAC/PNC) + \underset{(0.5720)}{0.4922} \ln(PAC/WPI) + \underset{(4.7977)}{4.2268} \ln(YPC)$
	n = 15 $\bar{R}^2 = 0.8839$ SSE = 0.2169 DW = 2.1119
	2) $\ln(QAC/POP) = \underset{(-0.2048)}{-3.2179} + \underset{(2.2152)}{6.9573} \ln(PAC/PNC) + \underset{(0.0080)}{0.0214} \ln(PAC/WPI) + \underset{(0.1287)}{0.2505} \ln(YPC)$
	n = 20 $\bar{R}^2 = 0.4816$ SSE = 4.2156 DW = 1.6023
	Chow Test: F = 29.49
I.D Shaving Creams	1) $\ln(QASC/POP) = \underset{(-5.9312)}{-9.0237} + \underset{(5.5986)}{1.0509} \ln(YPC)$
	n = 15 $\bar{R}^2 = 0.7068$ SSE = 0.1221 DW = 1.3349
	2) $\ln(QASC/POP) = \underset{(-2.9755)}{-5.3256} + \underset{(2.6947)}{0.5903} \ln(YPC)$
	n = 20 $\bar{R}^2 = 0.2875$ SSE = 0.4526 DW = 2.1975
	Chow Test: F = 7.04
I.E Residual	1) $\ln(QAPPR/POP) = \underset{(-3.9928)}{-21.7940} + \underset{(3.8428)}{2.5879} \ln(YPC)$
	n = 15 $\bar{R}^2 = 0.5318$ SSE = 1.5721 DW = 1.2674
	2) $\ln(QAPPR/POP) = \underset{(-1.5509)}{-7.7856} + \underset{(1.3724)}{0.8433} \ln(YPC)$
	n = 20 $\bar{R}^2 = 0.0947$ SSE = 3.5612 DW = 0.6657
	Chow Test: F = 3.29

(Continued)

Table B-III

(Continued)

Equation Number	
II. Household Products	1) $\ln(QAHH/POP) = -18.3497 + 2.3701 \ln(YPC)$ $(-8.5603)\ (8.9616)$ $n = 15 \quad \overline{R}^2 = 0.8607 \quad SSE = 0.2425 \quad DW = 0.5308$
	2) $\ln(QAHH/POP) = -11.3872 + 1.5037 \ln(YPC)$ $(-5.2694)\ (5.6848)$ $n = 20 \quad \overline{R}^2 = 0.6423 \quad SSE = 0.6599 \quad DW = 0.2632$
	Chow Test: F = 4.48
II.A Floor Wax	1) $\ln(QAHW/POP) = -25.6856 + 2.9773 \ln(YPC)$ $(-9.1357)\ (8.5830)$ $n = 15 \quad \overline{R}^2 = 0.8500 \quad SSE = 0.4171 \quad DW = 2.0841$
	2) $\ln(QAHW/POP) = -22.2224 + 2.5446 \ln(YPC)$ $(-7.2008)\ (6.7363)$ $n = 20 \quad \overline{R}^2 = 0.7160 \quad SSE = 1.3456 \quad DW = 1.8156$
	Chow Test: F = 5.791
II.B Detergents	1) $\ln(QAHS/POP) = -26.0764 + 3.1878 \ln(YPC)$ $(-3.7505)\ (3.7162)$ $n = 15 \quad \overline{R}^2 = 0.5151 \quad SSE = 2.5508 \quad DW = 0.9495$
	2) $\ln(QAHS/POP) = -9.7250 + 1.1527 \ln(YPC)$ $(-1.5615)\ (1.5122)$ $n = 20 \quad \overline{R}^2 = 0.1127 \quad SSE = 5.4809 \quad DW = 0.6653$
	Chow Test: F = 2.99

(Continued)

Table B-III
(Continued)

Equation Number

III. Veterinary Products

1) $\ln(QAV/POP) = \underset{(-7.9606)}{-21.1581} + \underset{(6.8130)}{2.2341} \ln(YPC)$

$n = 15$ $\bar{R}^2 = 0.7812$ $SSE = 0.3728$ $DW = 2.1272$

2) $\ln(QAV/POP) = \underset{(-10.8437)}{-19.1888} + \underset{(9.1844)}{1.9893} \ln(YPC)$

$n = 20$ $\bar{R}^2 = 0.8241$ $SSE = 0.4425$ $DW =$

Chow Test: $F = 0.4864$

IV. Pharmaceutical Products

1) $\ln(QAPH/POP) = \underset{(-4.4205)}{-17.0877} - \underset{(-2.1311)}{1.3749} \ln(PAPH/PNPH) + \underset{(2.0377)}{1.1862} \ln(PAPH/WPI) + \underset{(3.9969)}{1.9174} \ln(YPC)$

$n = 15$ $\bar{R}^2 = 0.7705$ $SSE = 0.5003$ $DW = 2.1377$

2) $\ln(QAPH/POP) = \underset{(-3.7834)}{-15.6998} - \underset{(-1.6286)}{1.0849} \ln(PAPH/PNPH) + \underset{(3.3947)}{1.7753} \ln(PAPH/WPI) + \underset{(3.3986)}{1.7521} \ln(YPC)$

$n = 20$ $\bar{R}^2 = 0.6366$ $SSE = 0.8635$ $DW = 2.0332$

Chow Test: $F = 1.597$

V. Paints

1) $\ln(QAP/POP) = \underset{(-11.0362)}{-21.5803} + \underset{(10.9573)}{2.6435} \ln(YPC)$

$n = 15$ $\bar{R}^2 = 0.9023$ $SSE = 0.2018$ $DW = 0.8782$

2) $\ln(QAP/POP) = \underset{(-12.4639)}{-18.5446} + \underset{(12.4442)}{2.2663} \ln(YPC)$

$n = 20$ $\bar{R}^2 = 0.8959$ $SSE = 0.3128$ $DW = 0.6782$

Chow Test: $F = 1.43$

(Continued)

Table B-III

(Continued)

Equation Number	
VI. Insecticides	1) $\ln(QAI/POP) = \underset{(-3.7637)}{-7.9354} - \underset{(-0.2107)}{0.0448}\ln(PAI/PNI) - \underset{(-0.7351)}{0.2399}\ln(PAI/WPI) + \underset{(3.3685)}{0.8837}\ln(YPC)$
	n = 15 $\quad \bar{R}^2 = 0.9278 \quad$ SSE = 0.0293 $\quad$ DW = 1.7781
	2) $\ln(QAI/POP) = \underset{(-3.5569)}{-12.6199} + \underset{(0.3662)}{0.1533}\ln(PAI/PNI) + \underset{(0.2596)}{0.1304}\ln(PAI/WPI) + \underset{(3.3235)}{1.4668}\ln(YPC)$
	n = 20 $\quad \bar{R}^2 = 0.7675 \quad$ SSE = 0.1985 $\quad$ DW = 1.2583
	Chow Test: F - 12.72
VII. Industrial Products	1) $\ln(QAIN/POP) = \underset{(-18.9522)}{-21.5554} + \underset{(17.0818)}{4.2517}\ln(IND)$
	n = 15 $\quad \bar{R}^2 = 0.9573 \quad$ SSE = 0.5357 $\quad$ DW = 0.9050
	2) $\ln(QAIN/POP) = \underset{(-24.7020)}{-20.8865} + \underset{(22.6131)}{4.1041}\ln(IND)$
	n = 20 $\quad \bar{R}^2 = 0.9660 \quad$ SSE = 0.6922 $\quad$ DW = 0.8349
	Chow Test: F = 0.76
VIII. Food	1) $\ln(QAF/POP) = \underset{(-2.3869)}{-5.8822} + \underset{(2.0532)}{0.6243}\ln(YPC)$
	n = 15 $\quad \bar{R}^2 = 0.2449 \quad$ SSE = 0.3205 $\quad$ DW = 1.7861
	2) $\ln(QAF/POP) = \underset{(-4.9606)}{-9.1608} + \underset{(4.5696)}{1.0329}\ln(YPC)$
	n = 20 $\quad \bar{R}^2 = 0.5371 \quad$ SSE = 0.4819 $\quad$ DW = 1.3944
	Chow Test: F = 1.31

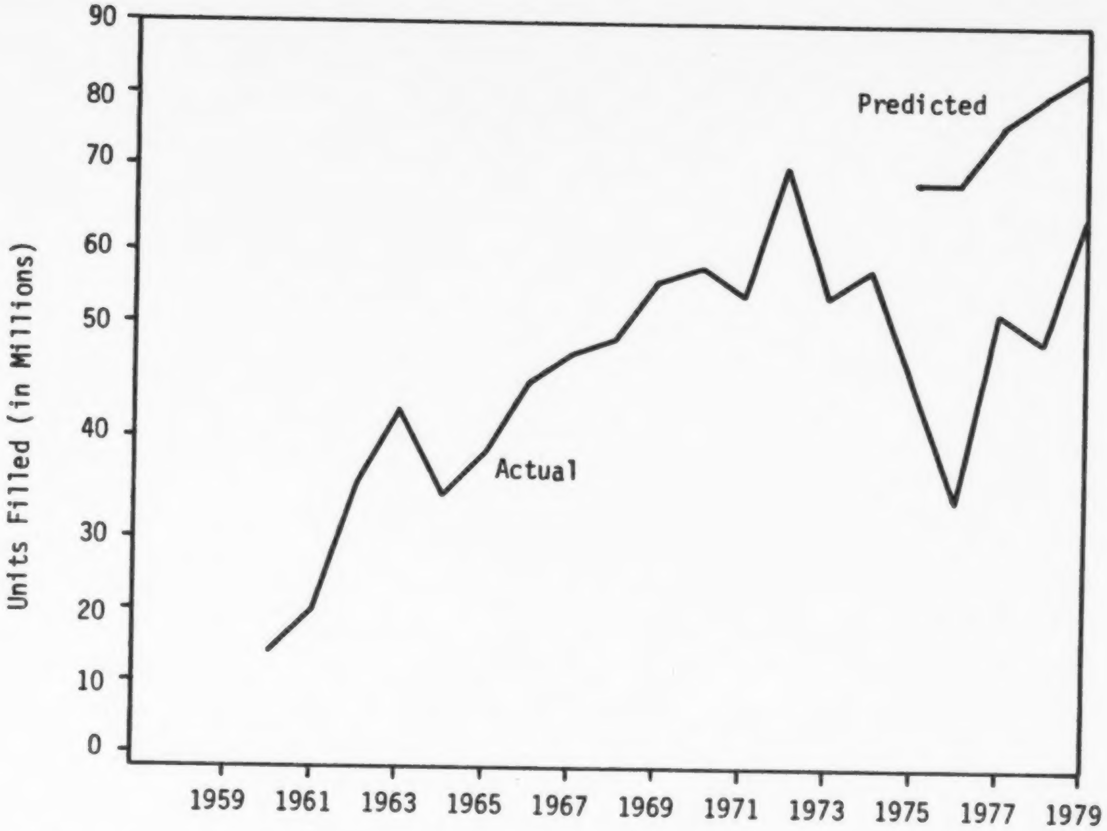
(Continued)

Table B-III

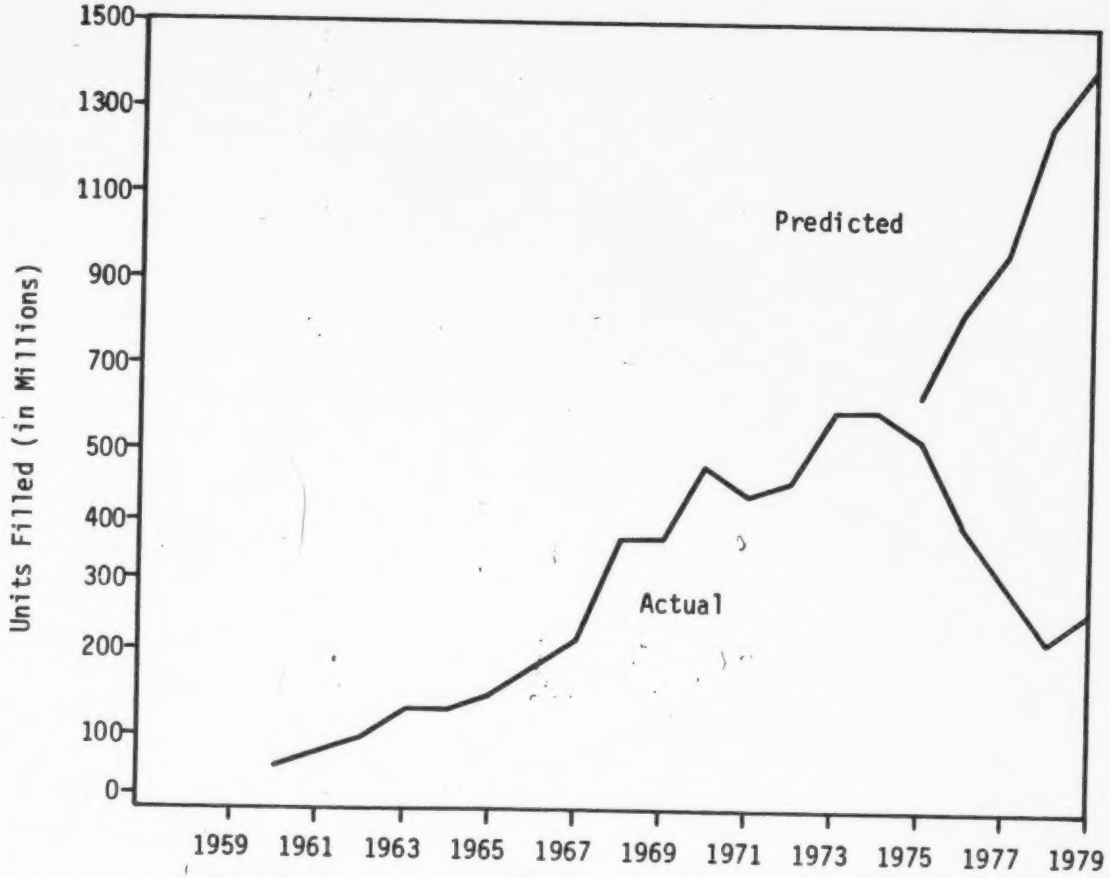
(Continued)

Equation Number	
IX. Automotive Products	1) $\ln(QAA/POP) = \underset{(-9.7089)}{-26.1125} + \underset{(9.1052)}{3.0214} \ln(YPC)$
	$n = 15$ $\bar{R}^2 = 0.8644$ $SSE = 0.3817$ $DW = 1.5039$
	2) $\ln(QAA/POP) = \underset{(-14.9388)}{-29.9267} + \underset{(14.2544)}{3.4952} \ln(YPC)$
	$n = 20$ $\bar{R}^2 = 0.9186$ $SSE = 0.5671$ $DW = 1.1292$
	Chow Test: $F = 1.26$

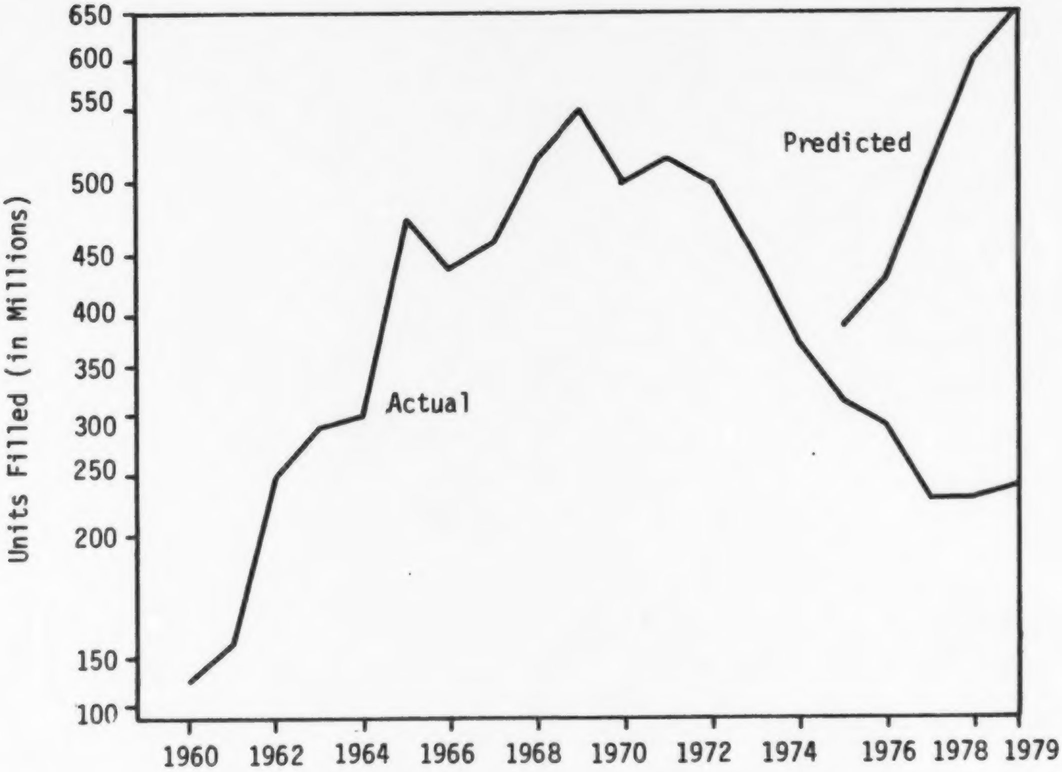
*The first equation for each product, where n = 15, is for 1960 to 1974. The second equation, where n = 20, is for 1960 to 1979.



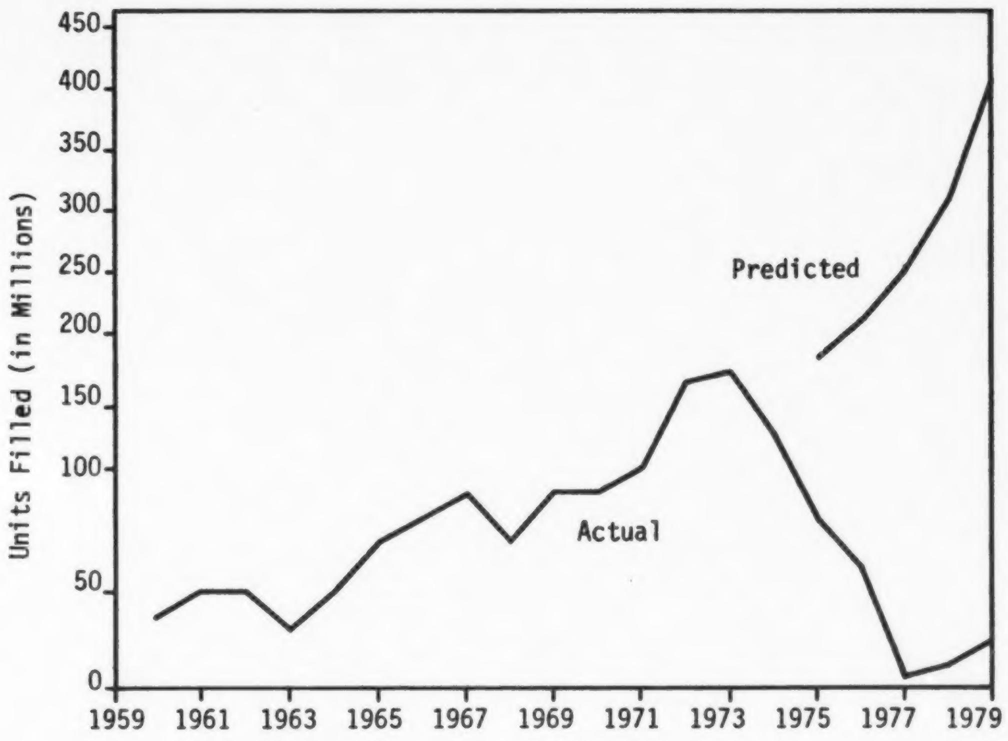
Graph B-1. Demand for Aerosol Personal Products (QAPP).



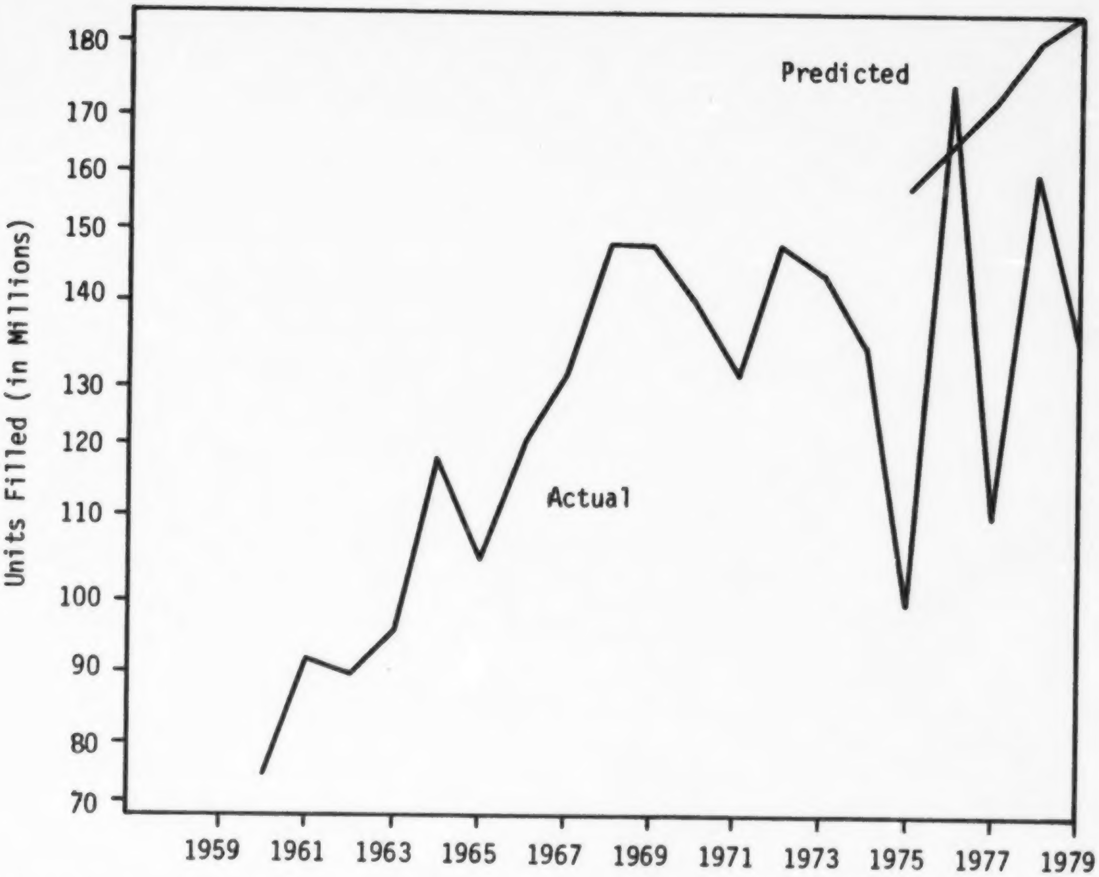
Graph B-2. Demand for Aerosol Antiperspirants/Deodorants (QADA).



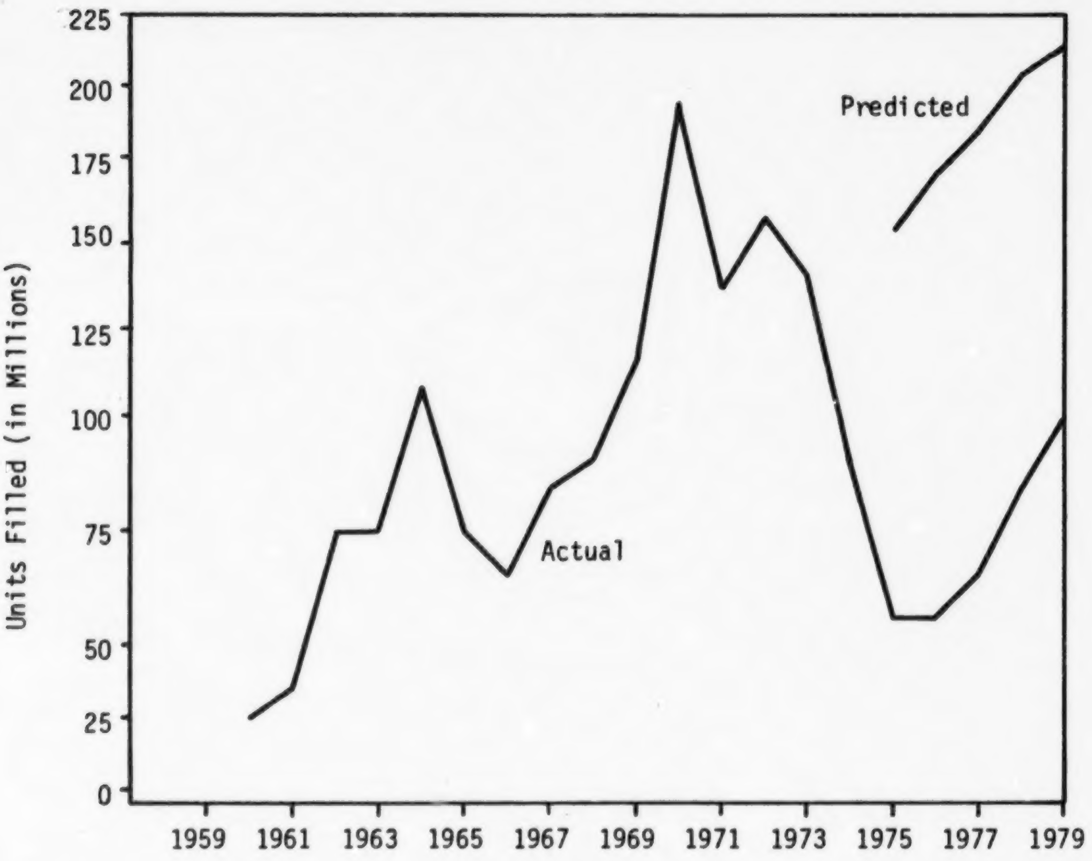
Graph B-3. Demand for Aerosol Hairsprays (QAH).



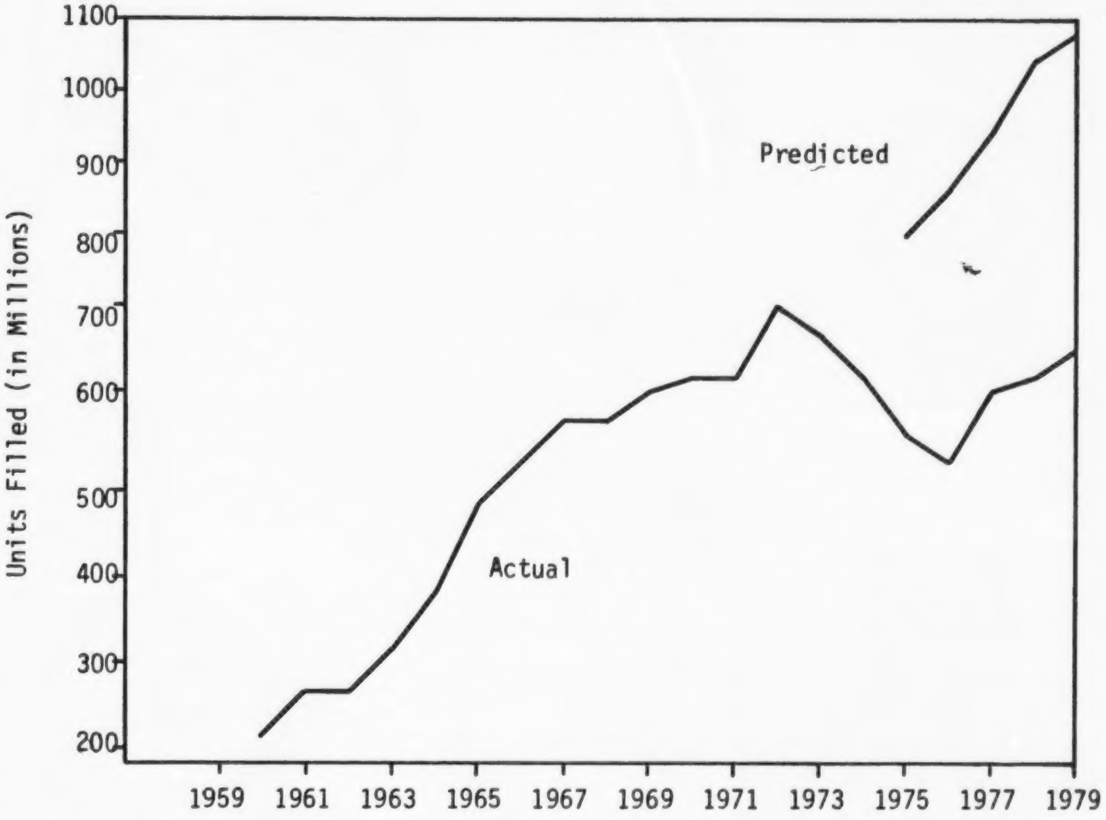
Graph B-4. Demand for Aerosol Colognes (QAC).



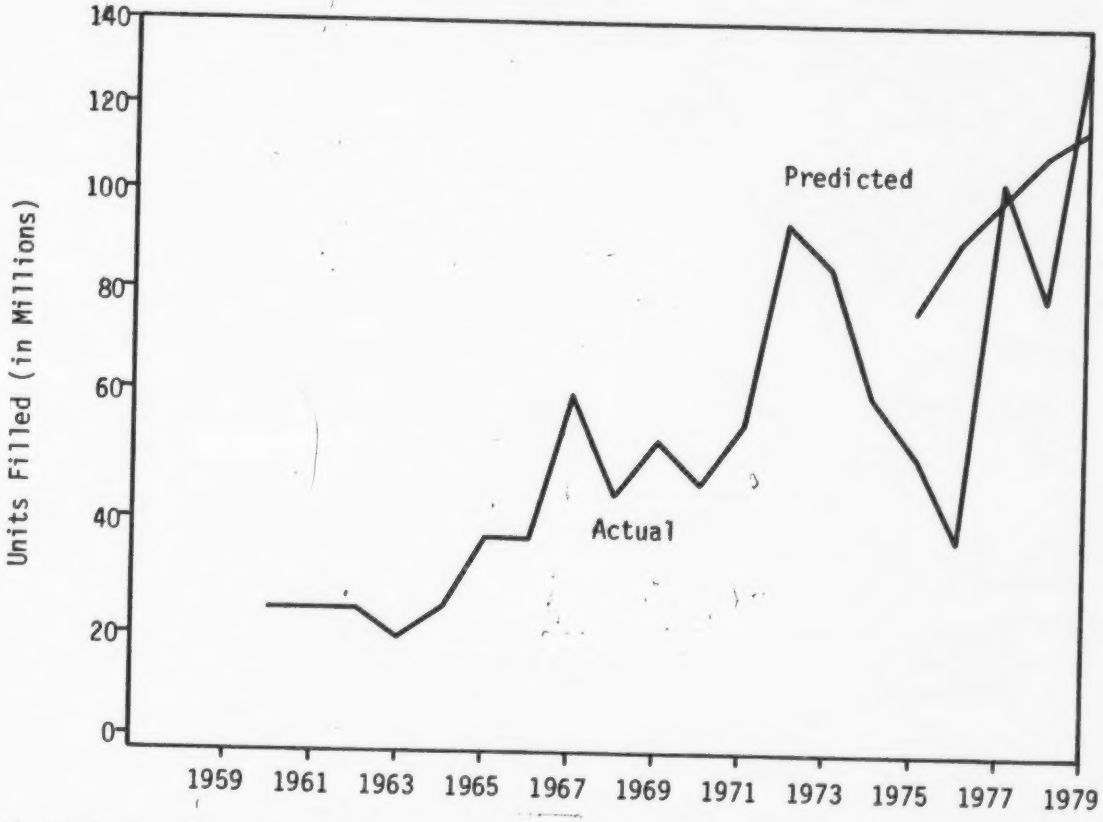
Graph B-5. Demand for Aerosol Shaving Creams (QASC).



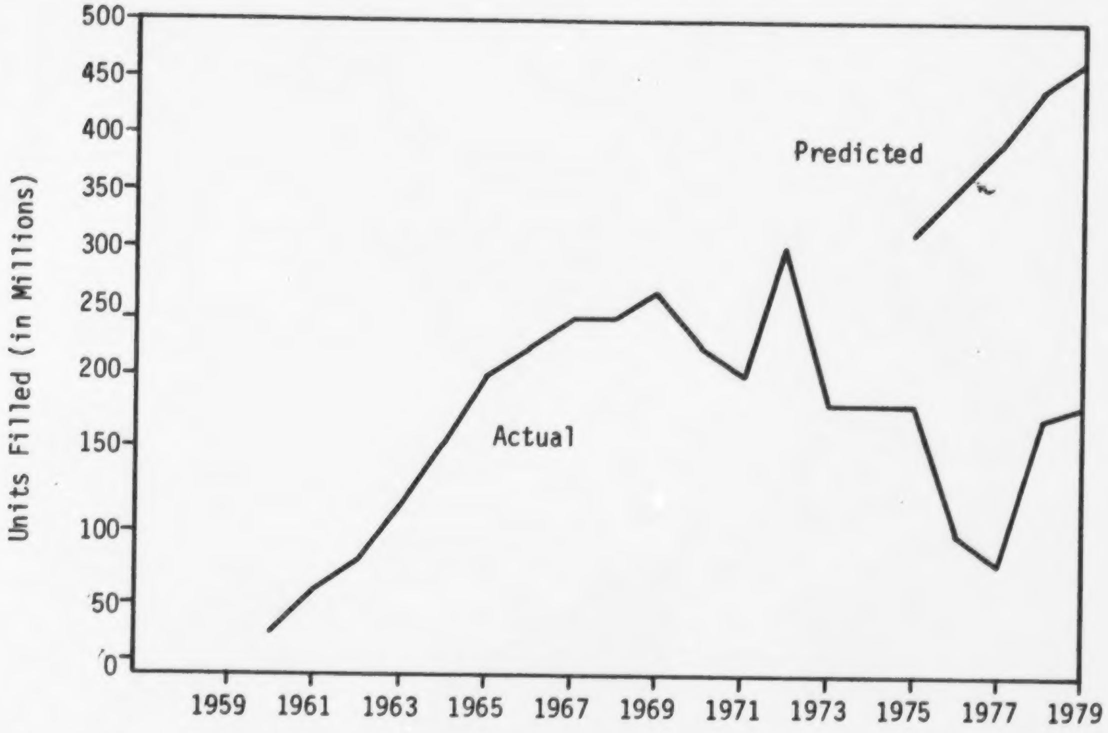
Graph B-6. Demand for Aerosol Residual Personal Products (QAPPR).



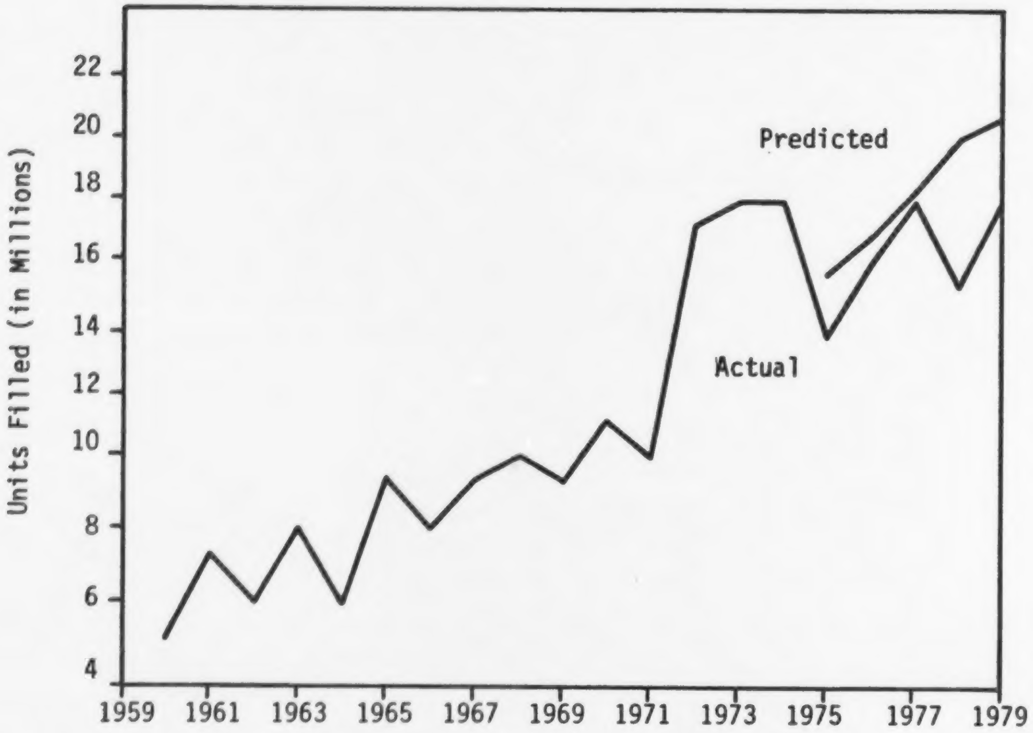
Graph B-7. Demand for Aerosol Household Products (QAHH).



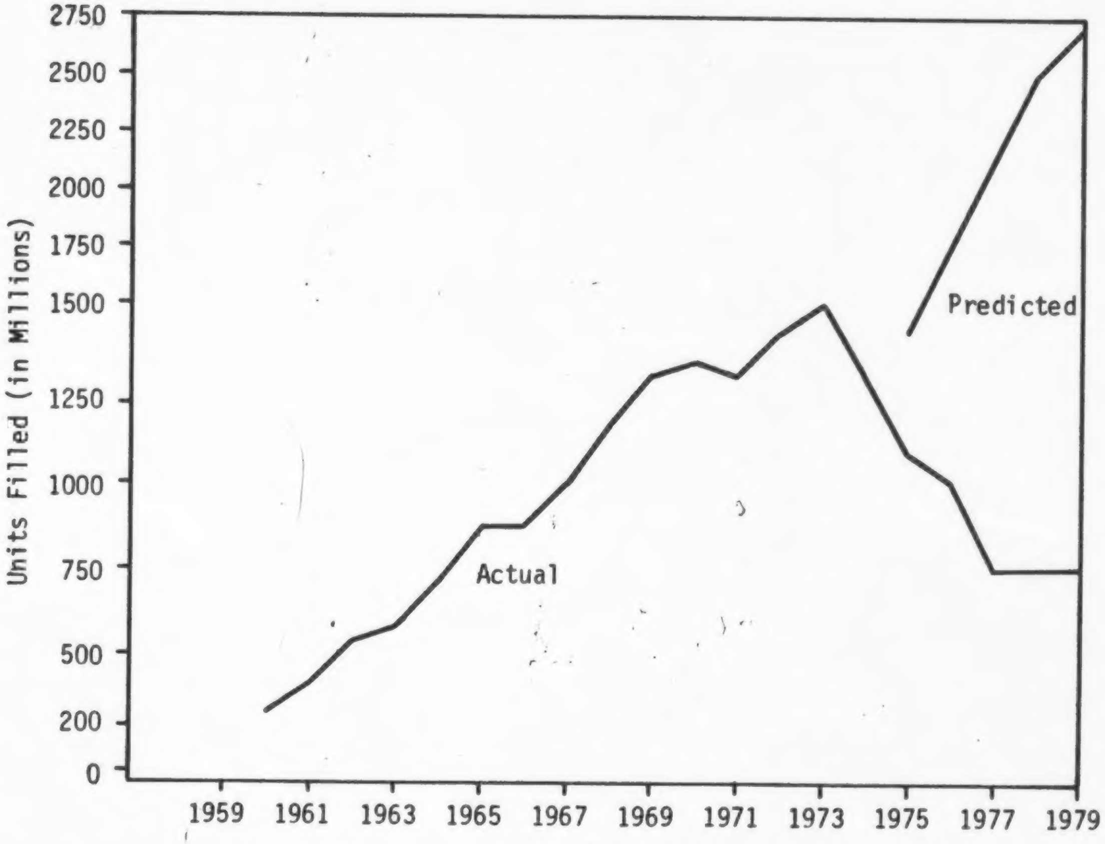
Graph B-8. Demand for Aerosol Household Wax (QAHW).



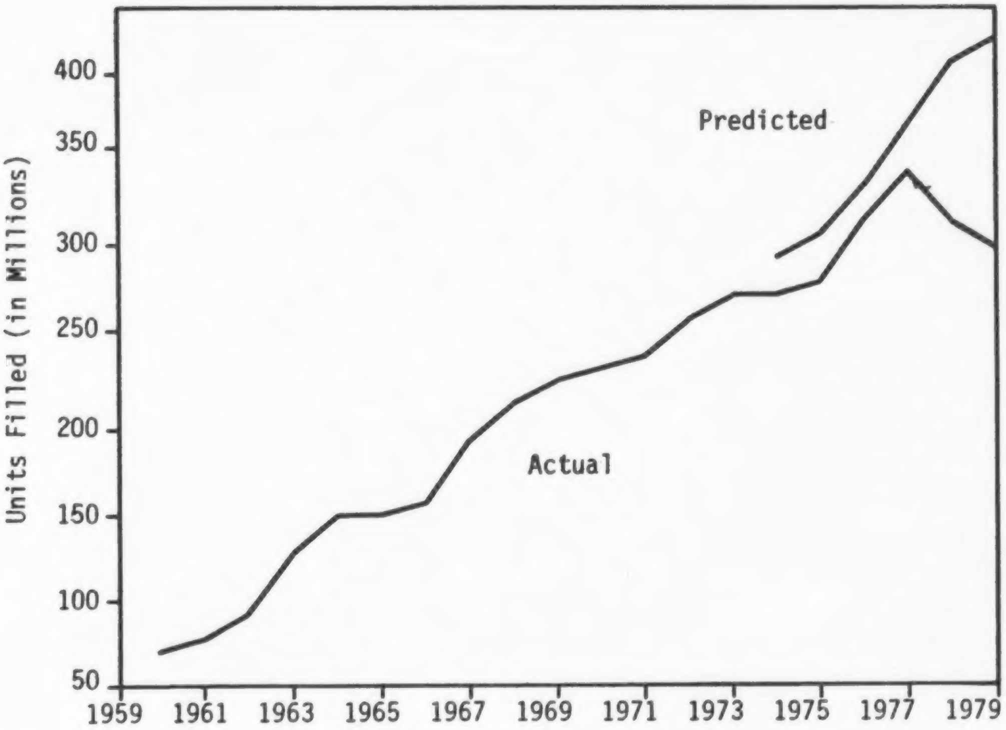
Graph B-9. Demand for Aerosol Starches and Laundry Products (QAHS).



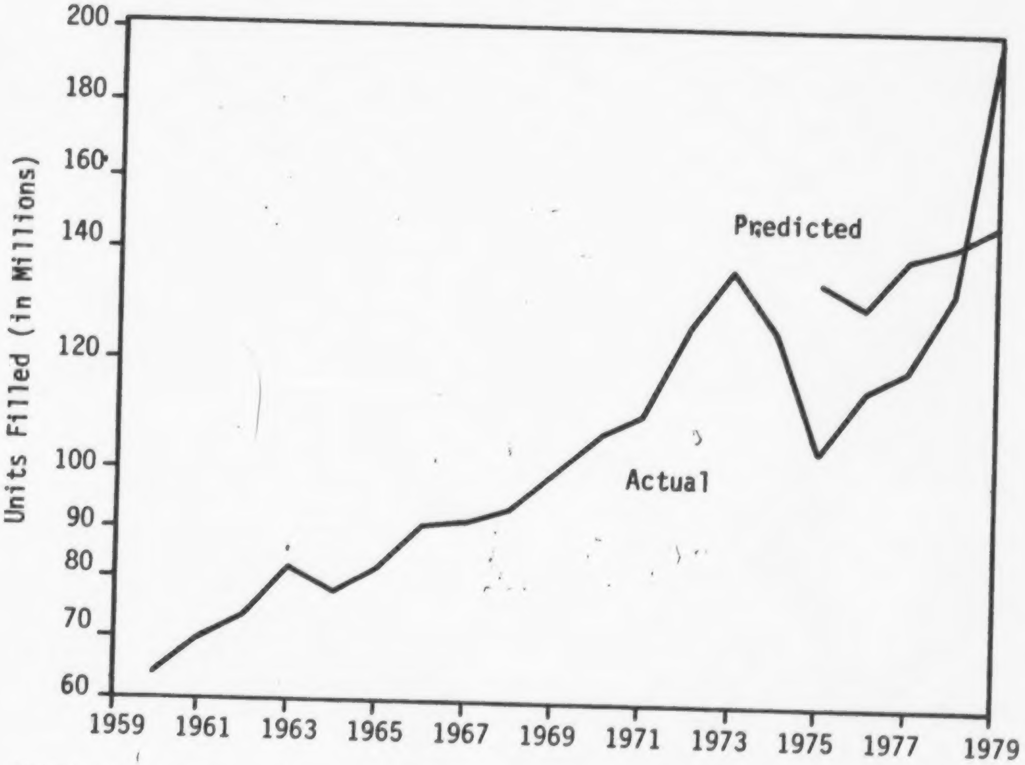
Graph B-10. Demand for Aerosol Veterinary Products (QAV).



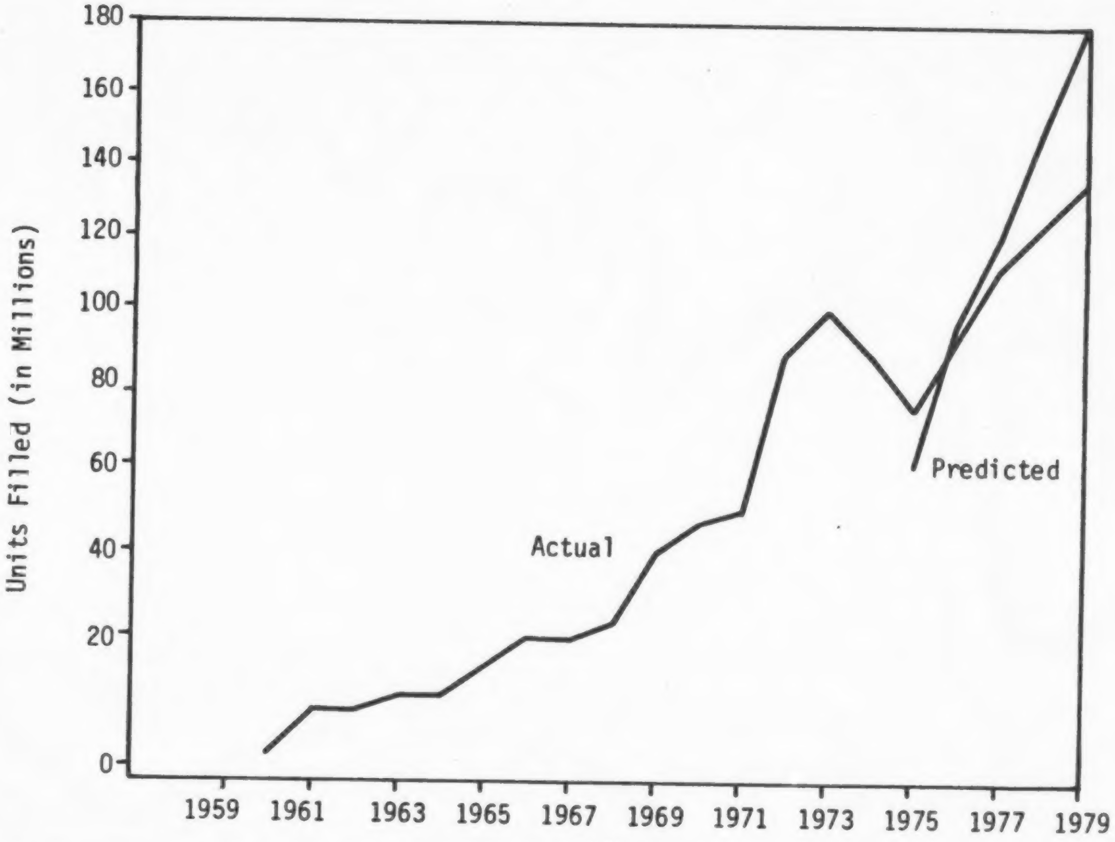
Graph B-11. Demand for Aerosol Pharmaceutical Products (QAPH).



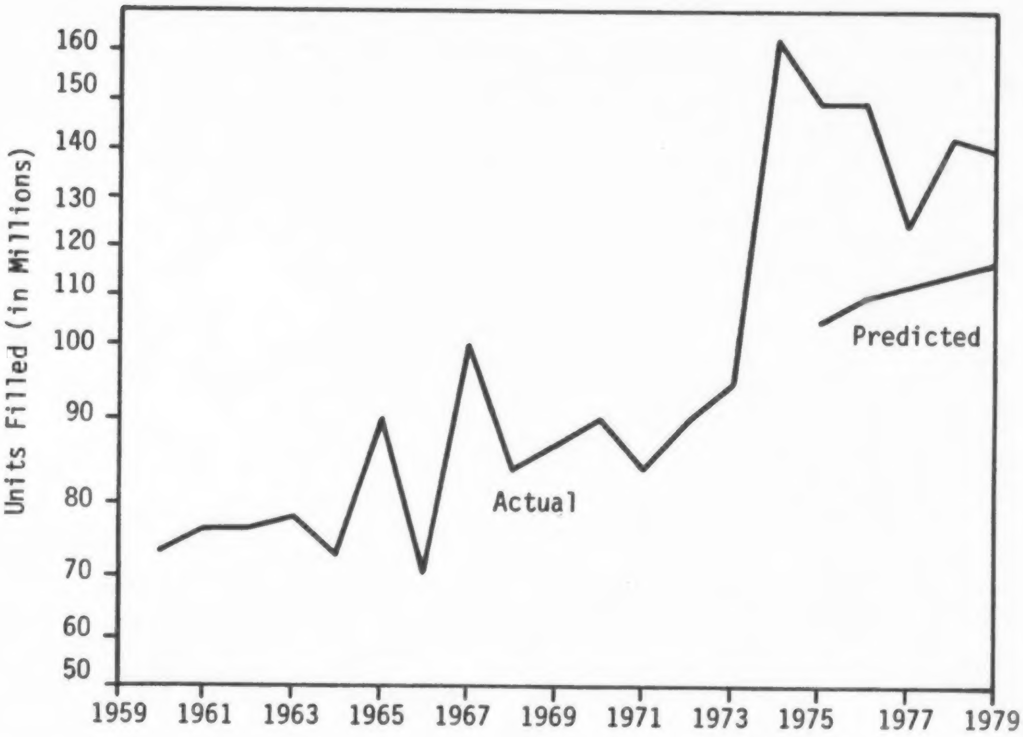
Graph B-12. Demand for Aerosol Paints (QAP).



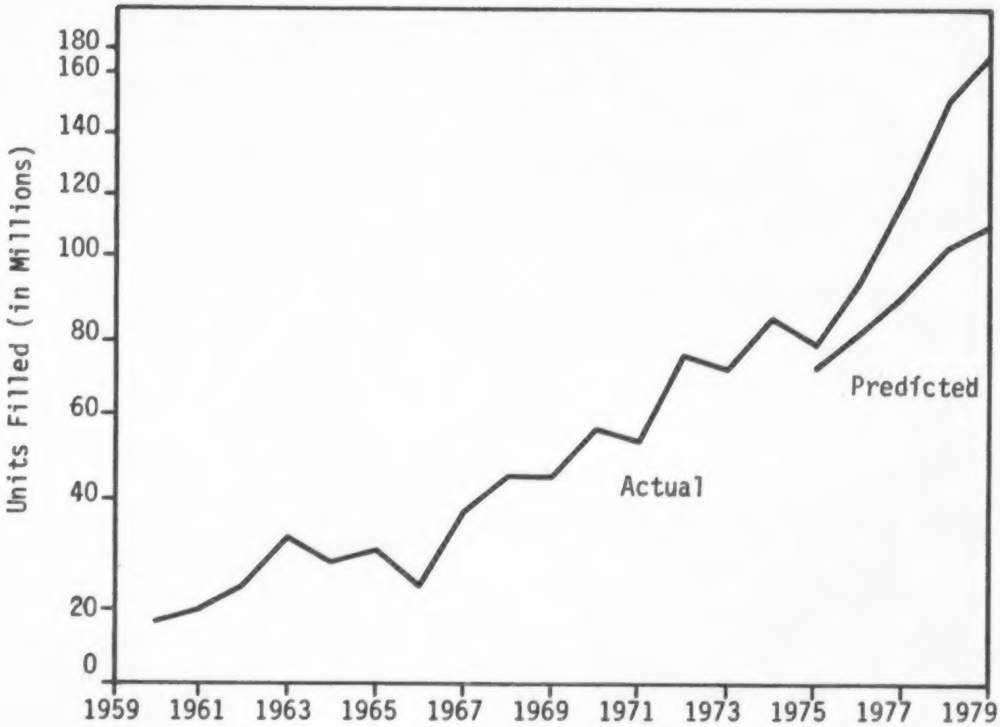
Graph B-13. Demand for Aerosol Insecticides (QAI).



Graph B-14. Demand for Aerosol Industrial Products (QAIN).



Graph B-15. Demand for Aerosol Food (QAF).



Graph B-16. Demand for Aerosol Automotive Products (QAA).

Appendix C

ALTERNATIVE WAYS OF MEASURING IMPACT ON PRODUCERS' PROFITS

This section evaluates two methods of analyzing the economic impact of regulation on producers' profits: the NPV of profit streams, and changes in profit rates. Changes in profit rates were specified in the contractor's scope of work, and the NPV of profit streams was not.

Profit Streams: The Appropriate Criterion of Impact on Profits

Comparing the NPV of future profit streams with CFC regulation with the NPV without CFC regulation is the appropriate way of measuring the economic impact of CFC regulation on producers' profits. The proper use of this criterion allows information to be included about (a) changes in the profit flows of firms or plants that remain in existence today, as well as (b) changes in profit flows of firms or plants that have withdrawn from the industry due to regulation. NPV calculations are standard practice in business and economics.

Changes in Profit Rates: A Less Appropriate Criterion

Another criterion of impact on profits is the impact on producers' profit rates, that is, the difference between profit rates with regulation compared to what they probably would have been without regulation. This criterion introduces two sets of analytic problems. One set of problems arise when this method is applied to an evaluation of the profits of existing firms; the other problem arises when this criterion is applied to plants that have gone out of business.

The Profit Rate Criterion Applied to Existing Firms. The profit rate measure of impact presents difficulties in assessing impact on existing firms for two reasons:

- o There is only an "impact" when increasing costs of regulation are not -- or cannot be -- passed on to the next stage-of-processing.

That is, lost output (lost sales) reduces the total profits of a company. This does not necessarily reduce profit rates unless there is an impact on costs (relative to prices, that is, a squeezing of the profit margin) that cannot be passed on to the next stage-of-processing. Then and only then are profit rates reduced. Then and only then is there "impact" in this area.

- There is also a scale problem. The profit rate criterion is totally independent of the scale of the dollar impact. A ridiculous example can be used for illustration. Assume the profits on auto industry sales decline 20 percent and that the profits on sales of the Chinese fortune cookie industry also decline 20 percent. Using the criterion in this study's scope of work, the economic impact on producers is the same. These numbers make no sense, because they are totally independent of the scale of each industry. The impact to the U.S. economy of a 20 percent decline in the auto industry's profits on sales is usually thought of as somewhat larger than a 20 percent decline in the Chinese fortune cookie industry's profits on sales.

The Profit Rate Criterion Applied to Plants that Left the Industry. The criterion cannot be applied to this situation because, by definition, the denominator -- sales -- goes to zero.

Appendix D

SUPPLEMENTARY INFORMATION ABOUT CAPITAL

This appendix contains supplementary information on the issues related to the assumptions about capital in this report. One of these is about CFC capacity, specifically, whether there was sufficient extant CFC capacity in 1973 to meet 1990 demand in the absence of regulation without further investment in plant and equipment. The second issue is whether capital equipment in the aerosol filling industry in 1975 had a remaining economic life of at least 15 years. Each topic is considered in turn.

CAPACITY IN THE CFC INDUSTRY

It is explicitly assumed in Chapter II of this report that capital equipment for CFC-11 and CFC-12, the two major aerosol propellants, had three characteristics:

1. It was dedicated
2. It became partially unemployed due to regulation
3. It had a remaining economic life until at least 1990.

The basis for these assumptions is discussed in Chapter II.

In addition to these explicit assumptions, there is an implicit one. This is that there was sufficient CFC-11 and CFC-12 capacity in 1973 to meet 1990 demand in the absence of regulation. This assumption is important because only that part of demand without regulation that could be met out of the capital stock that already existed prior to regulation is relevant to an analysis of profit streams foregone due to regulation.

The findings in Chapter V of this report are that CFC demand for CFC-11, -12, and -114 for aerosol use without regulation would have been 549 million pounds in 1990.* The question under consideration is this: Could this demand have been met out of capacity existing prior to regulation? The most reasonable assumption on the basis of scattered information is that it could.

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*The demand for all CFCs, not individual ones, were estimated in this report. CFC-114 had minor uses as a propellant prior to regulation.

The available data on 1990 output without regulation and 1973 nameplate capacity can be documented from several sources. The demand for aerosol and nonaerosol uses of CFC-11, -12, and -114 in 1990 in the absence of regulation is estimated to be 549 pounds for aerosol use (Chapter V) and 535 pounds for nonaerosol use [99, p. 36], or 1,084 million pounds in total. Capacity in 1973 can be estimated by adding 1977 nameplate capacity of 715 million pounds [99, p. 29] to estimates of 435 million pounds of nameplate capacity [36, p. 2-21 and industry estimates], as a result of plant closings due to decreased demand for aerosol propellants, for a total of 1,150 million pounds of nameplate capacity in 1973. Thus, the available evidence suggests that the 1990 hypothesized demand of 1,084 pounds of CFC-11, -12, and -114 could have been met out of the nameplate capacity of 1,150 million pounds estimated to have existed in 1973.

It should be noted that nameplate capacity is only an approximation to the amount of CFCs that can be produced; this report does not pursue this issue. Wolf [99, p. 38], however, notes that "actual capacity may exceed design capacity, sometimes by as much as 100 percent" but adds that "any assessment of the adequacy of current capacity for future production requirements is necessarily somewhat speculative."

REMAINING ECONOMIC LIFE IN THE AEROSOL FILLING INDUSTRY

It is explicitly assumed in Chapter II of this report that capital equipment in the aerosol filling industry had three characteristics:

1. It was dedicated
2. It became partially unemployed due to regulation
3. It had a remaining economic life until at least 1990.

More detail is presented here about the basis of the third assumption that states that capital equipment in the aerosol filling industry had a remaining economic life in 1975 of at least 15 years. The basis for this assumption is explored in greater depth because "capital" is not a single unit with a single lifespan, but rather a collection of various pieces of plant and equipment with varying periods of economic usefulness. Thus, it is only on average that capital has a certain lifespan.

The conclusions that are drawn in this note are based on discussions with engineers and businessmen in the aerosol filling industry itself. The findings, thus, represent a consensus of what was said rather than the results of a detailed industrial engineering study.

A filling operation consists of three sets of capital equipment, omitting R&D laboratories which vary too substantially in size from one filler to another to be included in the discussion. These three sets of equipment are: (1) storage and compounding equipment; (2) production line equipment; and (3) warehousing. The proportion of total initial capital cost of each of these is said to be approximately 35, 45, and 20, in 1981 dollars.

All capital equipment except that in the production line is said to have a long life, which engineers in the aerosol filling industry define as at least 30 years or "indefinite" depending on the source of information. That is, any maintenance repairs to this equipment is said to be so minor in terms of cost that it can be excluded from the discussion.

This leaves only the functional life of various equipment on the production line (45% of total initial costs) as the subject for closer scrutiny. The three major types of equipment in the production line are (1) liquid fillers, (2) UTC gassers, and (3) hot tanks and conveyors. The initial cost of this production equipment in 1981 dollars is said to be roughly 1/3:1/3:1/3. Liquid fillers have a long functional life, defined by engineers as at least 30 years. Hot tanks and conveyors have an intermediate life span, defined by filling industry engineers as 15 to 20 years. UTC gassers -- that is, 1/3 of 45 percent, or 15 percent of the capital equipment of a typical filler -- have a short life of 5 to 10 years.

It may be helpful to consider UTC gassers a bit more closely, since these have the shortest life span. A UTC gasser has a nameplate capacity of about 180 cans per minute. A very high volume filler operating at full capacity will run cans through at 180 to 240 cans per minute. The engineering rule-of-thumb is that a UTC gasser operating continually under these conditions (that is, at or above nameplate capacity) has to be rebuilt every 50 million cans, or once every 2-1/2 years. Rebuilding costs half the initial capital cost of the gasser. Thus, for every 100 million cans filled, the filler in effect buys a new gasser, although in actual practice the equipment is rebuilt twice. For a high volume filler who continually operates at full capacity, the functional life of a UTC gasser is equivalent to five years (2 rebuilds in 5 years). The more typical experience, however, is that a UTC gasser is not operated at nameplate capacity but considerably less than this; thus, the "typical" filler operating at "typical" usage is more likely to have to rebuild a gasser once every five years. An industry average of this is, therefore, somewhat more than five years, probably 7-1/2 years.

In light of these findings we conclude that it is reasonable to assume a remaining functional life until 1990 for capital equipment in aerosol filling operations. This represents, however, an averaging of equipment with a short life (UTC gassers) with those with a long lifespan (liquid fillers and storage and compounding equipment).

Appendix E

SUMMARY AND EVALUATION OF FIVE PROSPECTIVE STUDIES

The five studies reviewed here were produced between September 1975 and January 1978. They represent a wide range of objectives and, consequently, provide information on the CFC industry from a variety of perspectives. The Organization for Economic Cooperation and Development (OECD) takes a world view in its report. The Commerce report describes the separate segments of the CFC industry in terms of such variables as physical and dollar volumes, employment and payrolls, investments, and replacement costs and does so as of 1974. Arthur D. Little, Inc. (ADL) constructs a detailed picture of the linkages among the segments in terms of production processes, largely for 1973. Midwest Research Institute (MRI) is more concerned with the availability of substitutes from a technical standpoint. The report from International Research and Technology Corporation (IR&T) attempts to quantify the economic impact of alternative regulations on aerosol uses of CFCs.

In terms of providing a researcher with information about the possible impact of aerosol regulations, OECD, Commerce, ADL, and MRI supply pertinent information. However, problems arise if the researcher wants to check on the hardness or softness of this information since the methods used to compile the data in the reports are not always clear.

None of the studies except IR&T made a serious attempt to quantify the impacts of regulations. With Commerce abstaining, the remaining three studies do, however, make some kind of statement regarding impact. MRI based their statements on costs of alternative chemicals and/or delivery systems. ADL did not use quantified criteria but based their evaluation on their professional judgment. OECD drew much of its analysis from ADL.

IR&T approaches the problem of quantifying the regulatory impact by projecting what sales of CFC-using aerosols would have been through 1980 from a 1975 base year. They then estimate changes in value added due to nine alternative regulations and, by comparing the adjusted value added to the baseline figures from 1977 to 1980, derive losses due to each regulation. The study runs into trouble when the econometric work yields more problems than solutions. By proceeding with an ad hoc methodology that contains more assumptions and assertions than it does conclusions, they further compound the problem.

The problem was insufficient data. Commerce established a reasonable data base for 1974 and ADL added to it but apparently no one (including IR&T) had the resources to construct an adequate industry base to be used for developing projections. This would have required an estimation of supply and demand parameters which determine how decision-makers, both consumers and producers, will react to the imposition of a constraint in their system of doing things. Without such a data base, accurate quantified projections are unlikely.

THE IR&T REPORT

The stated objective of the IR&T report [36], entitled, "The Economic Impact of Potential Regulations of Chlorofluorocarbon-Propelled Aerosols," published April 1977, was to identify and quantify the impact of restricting the use of particular CFCs (CFC-11, -12, and -114). In the absence of specific regulations, IR&T hypothesized a series of nine alternative regulations, and their impact was estimated both for firms directly involved in the production and sales of aerosol products and for producers of precursor chemicals. Value added was the gauge used to estimate the economic impact on these groups of producers.

There are, however, several problems associated with using value added as an indicator of impact. The first centers on the potential confusion about the components of value added, and their limitations. Ignoring a few conceptual refinements in order to get to the heart of the matter, value added is the difference between the market value of goods leaving a plant and the total market value of the materials which went into producing them. The additional value of the "rearranged" materials is ascribed primarily to the actions of labor and capital in the production process. There are, therefore, two major components of value added -- wages and profits. Once some change in value added is estimated (whether positive or negative), the change refers to an effect on wages and profits combined. Additional information is required if one is to draw a conclusion about the distribution of that change between the two components of value added.

An additional problem with using value added arises from the extra care that must be taken if a decrease in value added is to be interpreted as a loss. It is possible that an impact will be a temporary displacement of labor or capital. To the extent that either finds its way back into production somewhere else in the economy, not all of the impact can be called a loss. Therefore, careful scrutiny is required when interpreting the results with respect to what has been affected and for how long. If this is done, value added is a legitimate, straightforward indicator of short-run change within an industry and can be compared across alternative regulations to estimate relative impact.

IR&T's approach involved estimating a baseline condition for the major groups of firms being considered through 1980, estimating changes in sales and prices due to regulatory restrictions, and calculating the decrease in value added that could be expected as a result. These changes were summarized by IR&T and are presented in Tables E-1, E-2, and E-3.

The value added changes in Table E-1 are presented for four years (1977-1980) for each regulatory scenario. Table E-2 distributes the net value added impact among the aerosol and chemical sectors, and Table E-3 distributes the aerosol and chemical sector impacts among marketers, fillers, and the manufacturers of containers, valves, and chemicals. Table E-2 indicates that the impact on the aerosol sector was several times larger than on the chemical sector. As to the further distribution of impact, Table E-3 shows that marketers had the greatest impact, followed by chemical manufacturers, container manufacturers, fillers, and valve manufacturers.

The offsets referred to in Tables E-1 and E-2 result from potential adjustments by fillers who convert their production lines to the alternative aerosols or mechanical devices. Such adjustments reduce lost total sales, and therefore, reduce the level of lost value added.

The nine scenarios used by IR&T include three timing possibilities and three levels of aerosol restrictions. These are summarized in Table E-4.

There is one puzzling aspect to IR&T's analysis; the report does not explain why an impact period of only four years was used. It can be argued

Table E-1

IR&T ANNUAL ECONOMIC IMPACTS -- ALL SCENARIOS

Value Added Losses (Gains) in
Millions of 1976 Dollars

	1977			1978			1979			1980		
Scenario	Gross	Offset	Net	Gross	Offset	Net	Gross	Offset	Net	Gross	Offset	Net
1	(0.1)	(6.0)	(6.1)	(47.7)	(6.1)	(53.8)	62.6	(6.2)	56.4	101.1	(8.9)	92.2
2	35.9	(6.0)	29.9	37.6	(6.1)	31.5	97.0	(9.1)	87.9	101.1	(8.9)	92.2
3	97.3	(10.6)	86.7	206.1	(9.0)	197.1	97.0	(9.1)	87.9	101.1	(8.9)	92.2
4	95.4	(14.8)	80.6	184.4	(23.4)	161.0	282.8	(25.4)	257.4	428.9	(26.7)	402.2
5	95.4	(14.8)	80.6	200.5	(24.8)	175.7	435.9	(29.1)	406.8	428.9	(26.7)	402.2
6	284.0	(20.2)	263.8	524.2	(42.8)	481.4	435.9	(29.1)	406.8	428.9	(26.7)	402.2
7	121.5	(24.7)	96.8	288.4	(52.9)	235.5	372.7	(62.2)	310.5	598.0	(64.3)	533.7
8	121.5	(24.7)	96.8	295.2	(53.3)	241.9	576.0	(62.2)	513.8	598.0	(64.3)	533.7
9	309.4	(26.4)	283.0	562.1	(60.7)	501.4	576.0	(62.2)	513.8	598.0	(64.3)	533.7

Note: The actual regulation reflects a scenario between numbers 5 and 6 on this table.

Source: The IR&T report [36].

Table E-2

IR&T FOUR YEAR TOTAL ECONOMIC IMPACTS FOR THE AEROSOL AND CHEMICAL SECTORS -- ALL SCENARIOS

(Value Added Losses in Millions of 1976 Dollars)

Scenario	Aerosol Sector	Chemical Sector	Total	Potential Offset	Net
1	45	71	116	27	89
2	74	198	272	30	242
3	257	245	502	38	464
4	713	280	993	90	903
5	864	299	1163	96	1067
6	1208	461	1669	119	1550
7	1094	286	1380	204	1176
8	1275	317	1592	204	1388
9	1584	461	2045	214	1831

Source: The IR&T report [36].

Table E-3

IR&T FOUR-YEAR ECONOMIC IMPACTS BY INDUSTRY SECTOR -- SCENARIOS 4, 5, AND 6

(Value Added Losses in Millions of 1976 Dollars)

Industry Group	Scenario 4	Scenario 5	Scenario 6
Marketers	458	573	818
Fillers	107 [17]*	122 [26]	163 [44]
Container Manufacturers	116	132	178
Valve Manufacturers	32	37	49
Chemical Manufacturers	280	299	461
Industry Total	993 [903]	1163 [1067]	1669 [1550]

*[ ] indicates net value added change after adjustment for filler offset.

Source: The IR&T report [36].

Table E-4

IR&T NUMERICAL DESIGNATION OF SCENARIOS

	Time of Implementation After Announcement		
Level of Restriction	30 mos.	18 mos.	6 mos.
Prohibition of CFC-11, CFC-12, CFC-114	1	2	3
All Fluorocarbons Restricted	4	5	6
Mechanical Alternatives Only	7	8	9

Source: The IR&T report [36].

that adjustments by industry began prior to 1977 and continued after 1980. Since an estimate of total impact was the objective of this study, some support is necessary for using the four-year time period. Had the objective been to estimate only relative impact among scenarios, the period of analysis would be critical only to the extent that the effects were distributed unevenly over time.

In addition to the impacts presented in Tables E-1, E-2, and E-3, IR&T estimated the following economic impacts:

- HCs would be the primary replacement propellant for CFCs
- Wholesale price reductions of 15 percent may occur with HC propellants
- Net job losses of 1,728 would occur under Scenario 4, 2,008 job losses under Scenario 5, and 2,772 under Scenario 6
- Conversion costs for small fillers would tend to be prohibitive
- Conversion costs for filling lines would range from $50,000 per line for fillers with HC filling experience to $500,000 per line for others, with an average of $250,000 per line
- Most of the chemical industry impact would fall on carbon tetrachloride manufacturers
- Hydrogen fluoride would lose 40 percent of its market.

As expected, the shorter the adjustment period, the greater the costs imposed on industry. Also, stricter regulations in terms of the number of substitutes allowed produce higher impacts. The more detailed results contained within the body of the report are, with a few exceptions, equally plausible. The authors reinforce the plausibility of their predictions by stating in the introduction that after conducting a sensitivity analysis the results of the study were found, on balance, to be "sufficiently insensitive to change in the underlying assumptions to warrant a high degree of confidence in this direction, magnitude, and rank" (emphasis added).

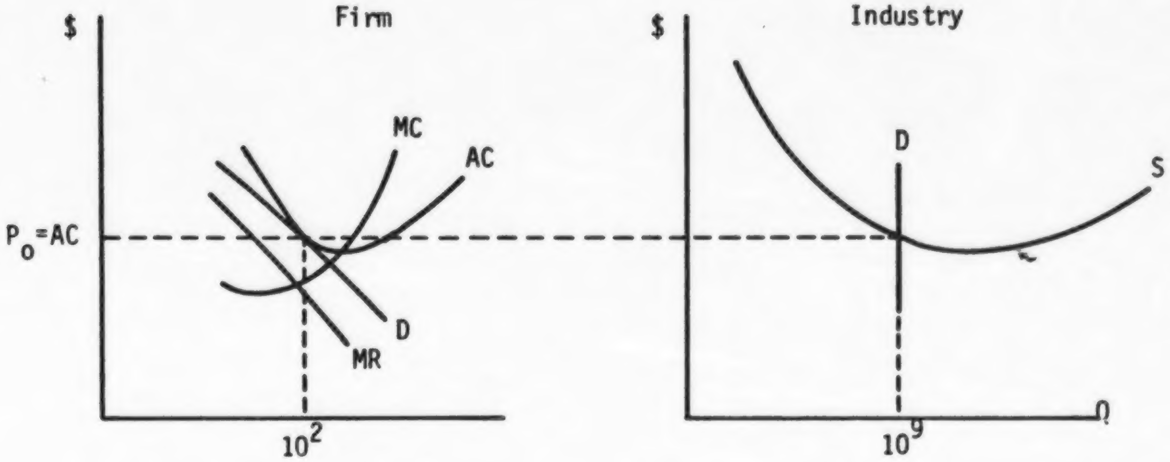
IR&T Method of Estimating Changes in Value Added

Conceptual Structure. In establishing its conceptual structure, IR&T made several assumptions regarding market structure. The two major assumptions are that the industry is monopolistically competitive and that demand for each product group (hairsprays, A/D, etc.) is perfectly inelastic over the relevant range of prices. The following statements, taken from different sections of the IR&T report, summarize IR&T's view of the conditions and relationships which determine the changes that can be expected to follow some degree of regulation.

- "The firms in each final product category of the industry are assumed to be monopolistically competitive."
- "Each product category as a whole faced a fairly inelastic demand within a relevant price range."
- "The industry supply curve is the summation of the individual firms' supply curves that are derived from unit costs ... the relevant portion of the (industry) supply curve is downward-sloping to the right."
- "...long-run equilibrium is reached when average price equals average total costs."
- [Because of the inelastic demand] "... it was valid to forecast total quantities demanded somewhat independently of prices."
- "Furthermore, we had established that price changes implied by the various regulatory options would at most be moderate."

The conceptual framework is summarized by IR&T in two graphs which are reproduced below.

The idea of monopolistic competition, with its differentiated products and use of advertising, has a great deal of appeal because of its correspondence with our perception of reality. However, there are limitations implicit in it. Of the two sides which must be considered, supply and demand, demand can be disposed of rather quickly. Whether industry demand is perfectly inelastic (totally unresponsive to price changes) is an empirical question. Since few goods have perfectly inelastic demand, its validity in the toiletry market is dubious except as an analytic convenience. This will be discussed further when data problems are addressed. With regard to the supply side, the conceptual validity of the IR&T presentation is problematic.



Graph E-1. Market Structure for the Aerosol Industry.

Where: AC = Average Cost; D = Demand; MC = Marginal Cost; MR = Marginal Revenue; P = Price; Q = Quantity of One Product Group; and S = Supply.

Source: The IR&T report [36].

The sight of a negatively-sloped curve is, to say the least, startling. IR&T arrived at this by using each firm's long-run average cost curve as its supply curve and summing across firms to get the response of the industry as a whole. There are several problems with this:

- It is the marginal, not average, cost curve that determines output levels
- When the marginal cost curves are summed across firms, a positively-sloped supply curve is the usual result, not a negatively-sloped curve.

However, the most significant problem is that in a monopolistically competitive industry, there is no supply curve. Supply is a relationship between price and production which is, by definition, independent of demand. Production levels in this type of market structure are determined in part by a marginal revenue function which is determined by demand. Therefore, production levels (quantity supplied) at each price are a partial function of demand. Quantity supplied and demanded are related, and the concept of supply is invalid.

In addition to the problem of the supply curve, another characteristic of monopolistic competition mentioned by IR&T -- the relationship which states that price equals long-run average cost -- is also a characteristic of a perfectly competitive market.

Despite these problems in the stated conceptual structure, their effect on the IR&T study was negligible for two reasons: the structure was not fully developed in the text, and it was not referenced throughout the study. Apparently, the conceptual structure was not used as the study progressed.

Data. Upon reviewing the study's data base, it became evident that, even if the conceptual structure had been developed, the data were insufficient to make use of the economic relationships that are inherent in the stated structure. To use this conceptual structure, data on industry demand, demand facing each firm, and the average cost structure of the major firms in each product group would have been required.

Data were gathered from journals published for the various affected industries, industry sources, consultants' reports, governmental organizations, and university researchers. Industry journals used by IR&T included such publications as Chemical Engineering, Chemical Week, and Advertising Age. Industry sources included CSMA, DuPont, and others unspecified. References to other research included the results of work by ADL, IR&T, EPA, and Shreve. Other sources included the Bureau of Census and the econometric work of d'Arge and Eubanks at the University of Wyoming.

The work by d'Arge and Eubanks consists of estimates of demand relationships for CFC aerosol products. The estimates express sales of the affected aerosols as a function of the price of the product itself, the price of substitutes, and per capita income. The equations are for the product groups they represent -- not demand facing each firm -- but rather, industry demand. By referring to Appendix B of the IR&T report, one can calculate demand elasticities inherent in the demand equations. Taking hairspray as an example, one finds price elasticities ranging from 2.0 to 0.9 depending on the equation, indicating a range from elastic to slightly inelastic, but giving no indication of a value sufficiently close to 0.0 to support the use of perfectly inelastic demand. IR&T needed the kind of data developed by d'Arge and Eubanks in order to make their projections, but IR&T was concerned about d'Arge and Eubanks data problems and specification errors and therefore did not use their results.

The same collection of data sources was used by researchers into this topic. This being the case, one must ask the question: How did IR&T manage to quantify the impact of regulation when the other research efforts could not? Apparently, IR&T extended the data sources in the following way: "The data are based on a considerable degree of judgment and assumption, and on fragmentary information from industry because the final 1976 figures have not yet become available" [36].

Method. IR&T presents their methodology in Chapter 3 of the report. After briefly reviewing the work of d'Arge and Eubanks, IR&T introduced their ad hoc method, which made it possible to "explicitly take into account the relevant structural changes caused by sudden and significant alterations in preferences and styles, population growth rates, laws, consumer incomes, product prices, and prices of substitutes" [36]. Their method has several major components:

- Assume the relevant impact would take place from January 1, 1977 to 1980.
- Estimate sales of each product category for each year in the period of impact.
- Assume each of the nine regulatory scenarios and estimate:
    - Change in sales for each product category
    - Change in prices for each product category
    - Change in employment
- Estimate change in value added for:
    - Marketers
    - Fillers

- Container manufacturers
- Valve manufacturers.

Several major assumptions were necessary in applying their ad hoc method. They are as follows:

- No change in technology
- No change in tastes and preferences
- No change in the types of substitutes that are available
- Population growth at 2 percent per year
- Income growth at more than 2 percent per year
- Baseline prices do not change from 1977 to 1980
- Production costs do not change within alternative delivery systems
- Relative prices across product groups are fairly stable
- For each alternative delivery system, cost/price ratios are constant
- The percentage mark-up of price over costs is constant.

From their conceptual structure, add:

- Demand is inelastic
- Price equals average cost.

By combining these assumptions with their data, their method of analysis produces the baseline presented in Table E-5. The methods used to produce Table E-5 are as follows:

- "Taking these factors into consideration, we feel that aerosol hairsprays could recover in 1977 to 370 million units (from an estimated 335 million in 1976) ... following 1977, the growth in hairsprays could be at least equal to population growth, thus producing a potential aerosol market of 393 million units by 1980. We estimate that the mechanical pump will not make additional inroads into this market. ... We estimate that

Table E-5

IR&T BASELINE PROJECTIONS FOR AEROSOL PRODUCTS

(Millions of Units)

	1976	1977	1978	1979	1980
Hairspray					
CFC-11/12	318	333	320	308	275
HC/CO_2	17	37	57	77	118
Total	335	370	377	385	393
Antiperspirant					
CFC-11/12	430	500	510	494	503
HC	0	0	0	26	27
Total	430	500	510	520	530
Other Toiletry					
CFC-11/12	171	200	214	229	245
Other	219	245	261	280	380
Total	390	445	475	509	545
Other Aerosol					
CFC-11/12	182	216	231	247	264
Other	1,163	1,223	1,309	1,401	1,499
Total	1,345	1,439	1,540	1,648	1,763

Source: The IR&T report [36].

alternative propellants will grow from 5 percent of the aerosol market (1976 estimate) to roughly 30 percent by 1980 ...."

- "Specifically, we forecast that the antiperspirant category would recover to 500 million units in 1977, ... and would grow at a fairly low rate -- estimated at 2 percent annually."
- "Our forecast assumes that [other toiletry products] would recover to 200 million units by 1977, and would maintain a 7 percent growth rate thereafter ... this fluorocarbon component is assumed to represent a constant 45 percent of the total category from 1977 on."

No other supporting method was presented with these statements.

In order to estimate the impact on value added for the nine alternative regulations, IR&T applies the fairly standard definition that value added is the difference between the cost of supplies and the price of the product as it moves to the next industry in the production chain. Consequently, the difference between the cost of supplies to aerosol fillers and the price paid by the marketers constitutes IR&T's value added for fillers. The wholesale selling price for each product minus manufacturing and marketing costs is value added to marketers; wholesale prices (versus retail prices) are used to estimate value added for retailers.

The initial cost of supplies is estimated from industry sources and contains the average cost of ingredients, containers, caps, and valves. Each regulatory alternative implies a different mix of ingredients (including propellants) and the cost of supplies change in response. With the assumption of fixed mark-up, fixed profit rate, and fixed ratio of price to cost, IR&T has, in effect, fixed value added per unit of output as determined by the estimates of 1976 costs of production. The impact therefore is determined by how sales are affected by changes in the basic cost structure.

IR&T's method for estimating changing sales is very similar to their estimating technique for baseline data. Invoking price inelastic demand, IR&T assumes no loss of total aerosol demand for each year in the forecast. What remains in terms of estimating the shift in value added is to estimate the shift in delivery systems used to meet the constant requirement for output in each product group.

Quoting from the report, for hairsprays under a limited fluorocarbon ban:

> "... it is assumed that the new ratio of hydrocarbon to fluorocarbon units would result in the same average price per unit (by 1980) as the old ratio in the Baseline Scenario ... we would then expect F-22 to phase out the F-11/F-12 system in 1978, achieving 50 percent of the total market in the year. By 1979, both hydrocarbon and F-22 systems would have reached their long-term shares of 50 percent each."

For the regulations which banned all fluorocarbons, IR&T states that "hydrocarbons could be expected to obtain 90 percent of the baseline aerosol market by 1979. The 10 percent reduction in total volume would be attributable to consumers refusing to switch from traditional fluorocarbon-based aerosol. Twenty percent of the market would be converted the first year, an additional 20 percent in the second year, and a further reduction of 40 percent by the third year following an announcement" [36]. Once again, the method consists of unconfirmed assertions of changes.

After arriving at their estimates, IR&T compared their results with work done by others. When they discovered a discrepancy between their estimates and those of Chemical Week, they concluded that Chemical Week's estimates were unrealistic. After applying their constant mark-up and constant cost/price relations, they compared their estimate of average wholesale price of aerosols with those of Shreve and found a "significant discrepancy". After some adjusting of numbers to make them comparable, IR&T suggested that Shreve's use of survey data produced biased results.

The ad hoc method, therefore, is to assume all important economic variables remain fixed and then assume a redistribution of output so that, in the face of changing costs, total demand does not change. Even some of the structural changes that the ad hoc method was to explicitly take into account (e.g., tastes and preferences) were assumed constant. The shifting of numbers seems to have been done in an organized manner, from sector to sector, but there is no estimating procedure in any economic sense of the word. The numbers represent an elaborate guess.

Presentation. A few words must be said about style; all of the observations, conclusions, and comments presented above are, obviously, built on what is perceived in the report. The IR&T report is extremely hard to follow if one is trying to duplicate its method. Information about data sources and use of data is scattered throughout the text rather than where the reader might need it to understand how all the information fits together. In addition, there are minor editing problems which cause difficulties, such as sales numbers that change from table to table (1975 sales of antiperspirants is 485 million or 510 million depending on the table), numbers within tables that do not sum correctly, and numbers in tables that do not correspond to numbers in the text. More serious editing problems cause the reader to flip from Chapter 2 to 3 to 4 to the Appendix and back again to verify a number.

Summary. The IR&T report presents a quantification of the impact of potential regulations on CFC propellants. Both the index of impact (value added) and the general approach used to reveal changes in value added are legitimate and straightforward ways to pursue the problem. Their conceptual framework, however, has major deficiencies with respect to the use of their chosen analytic model, monopolistic competition. The data requirements of that framework were not adequately met. The authors acknowledge that they were faced with the same paucity of data that confronted other consultants researching these issues. Unlike the other consultants, however, IR&T persisted in the effort to quantify economic impact through an ad hoc approach which is essentially a series of rules-of-thumb, guesses, and feelings. The authors also state that the results of their efforts can be regarded with "a high degree of confidence in their direction, magnitude, and rank."

Perhaps some areas of marketing research can rely on analysts who are so familiar with the conditions of a particular market that their feelings and hunches are more reliable than any model. Such an analysis may be accurate, but it does not allow anyone to trace and challenge, if necessary, the assumptions, calculations, and bases of data.

Since IR&T presented their conclusions as resulting from the application of a method (even though labeled ad hoc) which claimed to be based on a model of the CFC industry, they were evaluated accordingly. By those standards, they either misinterpreted or misunderstood their progress toward a description and prediction of reality.

THE COMMERCE REPORT

The Commerce report [76], entitled, "Economic Significance of Fluorocarbons," and published in December 1975, compiles a data base describing the CFC industry. Its objective centers around numerical description, where possible, of production and use of CFCs. In addition, it provides data on the value of capital and the levels of labor used in the CFC industry. This report makes no attempt to estimate the impact of potential regulation of CFCs.

Aspects of the CFC industry that Commerce describes are production in precursor chemicals, aerosol formulation, container and valve manufacturing, the refrigeration and air conditioning industry, plastics, and special uses of CFCs. It also discusses replacement and available alternatives, current research, energy and materials conservation, and international considerations. The type of data varies, but this report consistently attempts to provide numbers for output/sales (physical and dollar values), employment and payroll, and investment.

Because of the objective of this report, there were no conclusions *per se*. Commerce generates and presents a data base drawn from public and industrial sources, consultants' reports, and a university study. In reviewing the information available at the time the Commerce report was written, the quality of the data presented makes this report an excellent place from which to begin tracing regulatory impacts through the CFC industry.

Data. Section II of the Commerce report presents a summary of output and employment that is "dependent" on CFCs. Combining information from ADL, industry sources, and the Census Bureau, Commerce fills in gaps with their estimates and produces tables for 1974 employment and payroll, as well as 1974 dollar and physical production for chemical manufacturers, aerosol producers, refrigeration and air conditioning suppliers, and the plastics industry.

Section III describes the components of the CFC group. The tables show the chemical composition of thirteen CFCs, the distribution of end uses to total output, and the distribution of emissions from these end uses. The sources of the data are ADL and Commerce estimates. Section IV gives the reader a closer look at the chemical manufacturing industry. Data is developed showing distribution of the five most widely-used CFCs (CFC-11, -12, -22, -113, -114) according to value of production, companies and regions involved, chemical inputs, investment, and more. For this information, Commerce relied on its own estimates along with data from ADL and industry contacts.

Sections V through IX describe activity in each of the industry groups that use CFCs in their product. The data is more detailed for the aerosol industry because it is based on a separate study by R. R. Shreve at Northern Illinois University. DuPont provided a breakdown of aerosol production by product type, and Shreve's data is used for employment, investment, payroll, taxes, inventory, etc. for this industry as a whole. This type of information is available for the filling portion of the industry and, to a lesser extent, the container and valve industry.

Data on uses of CFC products is considerably less detailed. Data sources were ADL, the Census Bureau, and nonspecific industry sources. With the exception of figures presented for international trade, the rest of the Commerce report becomes rather speculative. The remainder of the report deals with development requirements for replacements of CFCs, the current availability of substitutes, ongoing research, and energy and material conservation considerations. These topics warrant speculation rather than the presentation of data.

Method of Presentation. The data are presented in a sequence that is easy to follow and the text forms an understandable and readable supplement to the tables it accompanies. For those sections in which the data is too sparse or wide-ranging to present in tabular form, the text remains consistent in form and readability.

One problem with the method of presentation is a result of the data being presented as one long conclusion. That is, the report presented what was found with respect to conditions in the CFC industry, but it does not report how it was found. In some instances this made little difference -- by quoting the Shreve report the responsibility for the method of collection could be passed on to Shreve. In other instances, however, the data was referenced as a Commerce estimate with only occasional indications of how those estimates were generated. Other sources, such as DuPont or ADL, were listed with tables, descriptions, and no indication of how hard or soft the numbers were.

Summary and Conclusions. The Commerce report describes the CFC industry as of 1974. Relying on previous work by ADL and Shreve, combined with industry contacts and public documents, this report constructs a reasonably extensive data base. The data presented concentrates on output, value of output, employment, payroll, and where possible, investment and capital replacement costs for the various segments of the economy involved in CFC manufacturing and use. Additional information was collected as sources permitted.

The data base presented in this report is by no means complete. A great deal of detail remains uncollected -- detail that would be of great assistance in describing the industries, the linkages, and the potential or actual impact of regulations. However, the effort and resources needed expand greatly as the detail becomes finer.

THE ADL REPORT

The stated purpose of the ADL report [4], entitled, "Preliminary Economic Impact Assessment of Possible Regulatory Action to Control Atmospheric Emissions of Selected Halocarbons," and published in September 1975, was to develop background information on 24 halocarbons, identify emission control strategies for the five most important CFCs, identify industry sectors which would be affected by potential regulation, and categorize the economic impact expected. ADL made no attempt to quantify the potential impact. The report concentrated on providing a detailed description of the interindustry links among CFC producers and users. The impacts are discussed in terms of a rank ordering (i.e., from severe to essentially none), for seven industry sectors. The conclusions of the report, with regard to the impact of nine regulatory alternatives, are taken from the ADL report and presented in Table E-6.

The basic approach consisted of collecting publicly-available numbers that described activity in the production or use of CFCs and supplementing that information with data developed through industry contacts. The data is extensive and ADL expresses confidence in its accuracy; however, they also caution the reader that there is no guarantee of statistical validity in the collection process.

Table E-6

ADL SUMMARY OF ECONOMIC IMPACT FROM REGULATORY OPTIONS

		Impact Sectors								
			Propellant Applications				Nonpropellant Applications			
			Aerosol Industry							
Regulatory Options		Producers of Basic Chemicals	Fillers	Can Manu-facturers	Valve Manu-facturers	Marketers	Refrigeration and Air Conditioning Manufacturers	Users of Blowing Agents (Rigid Foams)	Users of Solvents	Users of Chemical Intermed.
1.	A	2-3	1	3	1	2	1	2	5	5
	B	2	1	3	1	2	1	2	3	3
2.	A	3	1	3	1	2	4	3	5	5
	B	3	1	3	1	2	4	3	5	4
3.	A	3	1	3	1	2	5	4	5	5
	B	3	1	3	1	2	5	4	5	5
4.	A	3	1	3	1	2	4	3-4	5	5
	B	3	1	3	1	2	4	3-4	5	4
5.	A	3	2-3	5	2-3	3	1-2	3	5	5
	B	3	2-3	5	2-3	3	1	3	5	3
6.	A	3	2-3	5	2-3	3	4	3	5	5
	B	3	2-3	5	2-3	3	4	3	5	4
7.	A	3	2-3	5	2-3	3	5	4	5	5
	B	3	2-3	5	2-3	3	5	4	5	5
8.	A	3	2-3	5	2-3	3	5	4	5	5
	B	3	2-3	5	2-3	3	5	4	5	4
9.	A	5	3-5	5	3-5	5	5	4	5	5
	B	5	3-5	5	3-5	5	5	4	5	5

Impact Code:[a] 1 - Severe; 2 - Substantial; 3 - Moderate; 4 - Limited; 5 - Essentially None.

Regulatory Options: 1. Ban all but replacement uses of controlled chemicals after 6 months; 2. Regulation of nonpropellant uses and ban of propellant uses after 6 months; 3. No regulation of nonpropellant uses and ban of propellant uses after 6 months; 4. Government control of total chemical production after 6 months; 5. Ban all but replacement uses of controlled chemicals after 3 years; 6. Regulation of nonpropellant uses and ban of propellant uses after 3 years; 7. No regulation of nonpropellant uses and a ban of propellant uses after 3 years; 8. Government control of total chemical production after 3 years; 9. No regulation of nonpropellant applications and ban of propellant uses after 6+years.

Regulatory Suboptions: Chemicals Controlled: Suboption A -- F-11, F-12, carbon tetrachloride; Suboption B -- F-11, F-12, carbon tetrachloride, F-22, methyl chloroform.

[a] See text of report for definition of these terms.

Source: ADL [4].

Nine scenarios were developed that differentiated the possible regulations with respect to time frames and whether controls were placed on production, emissions, or sales. The criteria for impact considered the availability of substitutes, relative levels of sales, time needed for conversion, market interdependencies, and cost factors, etc. The economic sectors include producers of chemicals, firms using CFCs as intermediate chemicals, and firms using CFCs for propellants, refrigerants, blowing agents, or solvents.

The approach is strictly descriptive and, with respect to the impacts, judgmental. The fact that the ADL report promises very little in terms of estimating impacts speaks more to the availability of data and the resources available to collect it than it does to the appropriateness of the approach.

Data. The report is divided into six substantive chapters -- halocarbon production and use, emissions, emission sources, conversion timetables, industries affected by the regulatory alternatives, and economic impacts. Within each of these chapters, ADL presents their data from various perspectives. In a series of tables, charts, and text that references data sources and unexplained ADL estimates, the reader discovers a wealth of information on CFC production, use, and side-effects -- 105 tables and 18 figures.

ADL presents data on CFC capacity by producer, yearly U.S. production for 1960 to 1974, yearly consumption by end use, world production and capacity, and similar data for precursor chemicals. Emission data (in Chapter 3) is also distributed according to industrial sector, CFC pattern (i.e., CFC-11, -12, -22, etc.) and end use patterns for both the U.S. and the rest of the world. Chapter 4 discusses in detail the technologies of the various end uses of CFCs. The reader is familiarized with aerosol cans, refrigerators, dry cleaning plants, degreasers, polystyrene blowing equipment, and more.

The information more relevant to discussing impacts begins with the conversion timetables in Chapter 5. The discussion of timetables is divided among the major industry sectors identified earlier, moving from raw materials to consumer products. The conversion steps considered range from product development and testing, to building new plants, to continuing with existing facilities. Total time requirements and phasing possibilities are considered with the inherent uncertainties of such operations covered by way of optimistic and pessimistic alternatives.

This level of detail is maintained throughout the remainder of the report. A great deal of information is supplied about the chemical industry and the end-product users of CFCs in terms of capacity, sales and, where possible, employment. This description (found in Chapter 6) serves as the major reference point for the discussion of potential economic impacts that follow in Chapter 7. Chapter 7 synthesizes data on emissions, sources, hypothetical regulations, and interindustry links, and makes judgments concerning impacts. The discussion remains at a conceptual and hypothetical level. That is, generalized relations among capital equipment, labor, and raw materials are combined with potential substitutions and trade-offs implied by the regulation. The possibilities seem well-considered and consistent with basic economic principles. As a result, the judgments about impacts seem plausible.

To produce the data contained in this report, a great deal of information was assembled, sorted, and, in some cases, extended. Throughout this report the tables summarizing what has been collected have references that fall into three general categories: industry sources, publicly-available documents, and ADL estimates. Unfortunately, it is impossible to tell where the dividing lines are between sources that are internal or external to ADL. There is also little effort to describe the estimating procedures used to extend the original information.

Impact Assessment. The regulatory options summarized by ADL are presented below.

Summary of Regulatory Options

Immediate Restrictions

1. Ban All But Replacement Uses of Controlled Chemicals After Six Months
    - Restricted Chemical Set A
    - Restricted Chemical Set B
2. Regulate Nonpropellant Uses and Ban Propellant Uses After Six Months
    - Restricted Chemical Set A
    - Restricted Chemical Set B

3. Do Not Regulate Nonpropellant Uses and Ban Propellant Uses After Six Months
    - Restricted Chemical Set A
    - Restricted Chemical Set B
4. Institute Government Control of Total Chemical Production After Six Months
    - Restricted Chemical Set A
    - Restricted Chemical Set B

Restriction After Three Years

5. Ban All But Replacement Uses of Controlled Chemicals After Three Years
    - Restricted Chemical Set A
    - Restricted Chemical Set B
6. Regulate Nonpropellant Uses and Ban Propellant Uses After Three Years
    - Restricted Chemical Set A
    - Restricted Chemical Set B
7. Do Not Regulate Nonpropellant Uses and Ban Propellant Uses After Three Years
    - Restricted Chemical Set A
    - Restricted Chemical Set B
8. Institute Government Control of Total Chemical Production After Three Years
    - Restricted Chemical Set A
    - Restricted Chemical Set B

Restriction After Six Years

9. Do Not Regulate Nonpropellant Uses and Ban Propellant Uses After Six Years
    - Restricted Chemical Set A
    - Restricted Chemical Set B

Set A: CFC-11, CFC-12, carbon tetrachloride.

Set B: Set A plus CFC-22 and methylchloroform.

For each option, ADL derived the following criterion for impact.

- Severe Impact. A severe impact implies that most companies in the sector will be affected, at least to a moderate degree (some seriously), and more than 40 percent of the directly related business activity, of which chemical production or chemical consuming production is a part, will be ended or significantly disrupted.
- Substantial Impact. A substantial impact implies that some firms in the sector will experience at least a moderate and in some cases a serious impact, and a significant portion (greater than 10% but less than 40%) of the directly related business activity, of which chemical production or chemical consuming production is a part, will be ended or significantly disrupted.
- Moderate Impact. A moderate impact occurs when a few firms in a sector experience a moderate impact on sales or profits, and no more than a small portion (less than 10%) of the directly related business activity, of which chemical production or chemical consuming production is a part, will be ended or significantly disrupted.
- Limited Impact. The limited impact category applies to situations in which regulations have an impact on firms in a sector or on production in a sector related to the controlled chemicals only through increases in product prices. If a reduction in a chemical's production or the imposition of a tax results in a large increase in the chemical's price, the resulting product price increase in sectors continuing to use the chemical may result in some unit sales decrease. Equipment upgrading to reduce atmospheric emissions also raises product prices and fall in this category if the regulation imposes no other limitations on continued production. While the magnitudes of these price and sales changes have not been defined, the instances when they may occur have been identified as limited impacts.
- No Impact. The no impact category covers instances when the proposed regulations have essentially no impact on the firms or on

production. Very small price increases are possible under this category.

In assessing the impact of each prospective regulatory option, the ADL report considered each sector involved in CFC production and use as well as the relative contributions of each sector in terms of emissions. Then, for each alternative regulation, ADL discussed economic impacts in terms of the severity of the constraint it would impose on each sector. Severity hinges on the availability of substitute inputs and the possibility of a sector having to redesign its product. Each discussion is qualitative and judgmental and makes no attempt to be definitive. The more the sector is constrained and the fewer the adjustments available to it, the greater the impact. However, there is a problem in understanding the impact ranking. The wording that describes a severe, substantial, and moderate impact is neither definitive nor explanatory. Part of the definition of a severe impact is that most companies will experience at least a moderate impact. However, when one looks to "moderate impact" to see what that phrase means, we find, in effect, that moderate means moderate. This unenlightening definition is perhaps a minor point; however, if we are to accept the plausibility of ADL's judgments, we should, at the very least, have a criteria defined in terms which are not self-reflective.

Presentation. ADL put together a commendable presentation of the CFC industry. It holds together well and provides an excellent reference for those wishing to know how these industries and processes are linked. The information proceeds in an orderly and understandable fashion, with the earlier chapters establishing a basis for the later chapters. The sheer volume of data presented and the many perspectives from which it can be viewed sometimes impedes comprehension. This problem seems to be a function of the breadth of the subject rather than the organization of the report.

Summary and Conclusions. Of the five reports discussed here, the ADL report contains the most comprehensive description of the economic sectors relevant to CFCs and their relationships to each other. ADL compiled statistics that describe production, employment, investment, and capacity for CFC-related chemical manufacturing and end uses. Once the separate sectors are defined, their roles in emissions and emission reductions are described.

Finally, a conceptual analysis indicates potential disruptions as alternative regulations disturb the linkages between sectors.

Though the information supplied by ADL is wide-ranging, it is nonetheless a bit spotty. Unfortunately, the basic market parameters needed for supply and demand analysis of the industries and a quantification of the potential disruptions of regulations could not be developed. The judgmental approach used by ADL seems well thought out and reasonable as an expression of what might happen. However, without better data, and the market analysis that it makes possible, what might happen is nothing more than speculation.

THE MRI REPORT

The MRI report [47], entitled, "Chemical Technology and Economics in Environmental Perspective," Task 1, published March 1976, approaches the CFC regulatory question with the objective of exploring the technical feasibility and the basic economic considerations of using other chemicals or delivery systems as alternatives to CFC-11, -12, -13, -113, and -114. They explicitly state that their interest is in technical feasibility. That is, they begin with the statement that the higher costs of alternatives have already been accepted by the consumer; therefore, costs were discussed but not used to exclude any alternative.

With respect to aerosols, MRI concludes that "in all but a few cases, alternative methods of delivering these products are available and on the market" [47,48]. They further conclude that trade-offs exist among the alternatives that are on the market with respect to cost, effectiveness of the delivery systems, and safety. Finally, they find that converting to other propellants or delivery systems could involve substantial costs, and that the conversion to carbon dioxide could cost from $7,000 to $50,000 per line.

These conclusions were reached by "working closely with industry." Many of their references were personal, and sometimes confidential, communications with some member of industry. In addition, reports and communications with ADL, Inc. were heavily used, as were other reports published by EPA.

MRI's approach is difficult to label. The report seems to be more of a qualitative commentary than anything else. For aerosols, they describe the development of the industry, evaluate selection criteria and potential alternatives, describe the alternatives and who produces them, and finally, they make statements about economic consequences. The information seems not so much a product of research as it does a synthesis of what is known.

Data and Its Presentation. The aerosol data are found in Section 2. The boiling point of gases, the difference between a two-phase system and a three-phase system, and a variety of chemical and physical properties of 40 chemicals and gases are discussed along with the positive and negative aspects of the physical and chemical properties. Some of the regulatory alternatives are eliminated because there seems to be little benefit to using them. Fifteen alternatives are eliminated in just this way, including sulfur dioxide because of toxicity, and vinyl chloride because of its carcinogenic properties. The remaining candidates were presented in an "it is nontoxic but it is more flammable and it has a low vapor pressure" format (i.e., in terms of relative levels of major characteristics).

The discussion described above was extensively referenced. The reader is referred to footnotes as he is told that a gas has a coarse spray or is approved as a fast food additive or has problems that can be overcome with a valve redesign. The sources referred to consist of industry publications, government reports, consulting reports, and personal communications with industry.

The discussion of economic consequences presented in Section 8 is similarly matter-of-fact. The basic conclusions concerning the availability of substitutes are presented in the first section of this review.

Summary and Conclusions. The MRI report takes up the question of the substitutability of CFCs as an input in the several product groups that rely on them. There is also a smooth presentation of chemicals, processes, properties, and trade-offs in addition to a discussion of the present cost of alternative systems or chemicals.

The matter-of-fact presentation seems inappropriate to an area that five years later is still filled with controversy. Much of the material presented may well be factual for some portions of the industry and, due to process differences, biased in other portions; there is no way to tell. MRI did not deduce anything in their report, nor did they combine facts and reach conclusions. They tried to collect and report information on what is possible with respect to alternatives to CFCs. It would also have been more enlightening if they had evaluated the information they gathered. In addition, it would have been helpful if a discussion of economic feasibility had been included before conclusions were reached concerning the "availability" of substitutes. Still, the engineering information presented in this report is a piece of the puzzle that must be examined.

THE OECD REPORT

The objectives of the OECD report [58], entitled, "The Economic Impact of Restrictions on the Use of Fluorocarbons," and published January 1977, are by far the most ambitious of the five reports. Their stated objective is to identify activities of international organizations, compile an inventory of research on the chemistry and biology of the ozone depletion hypothesis, identify substitute CFCs, identify alternative regulations for controlling CFCs, and study the economic, technological, and social impact of those alternatives. The scope of their organization included 25 countries.

Their conclusions are a mixture of descriptive statistics that show that, as a group, the OECD countries consume most of the CFC products produced (i.e., exports are about 7.3% of production). The U.S. is the major producer of CFCs (49.8%), and OECD's conclusions show that the impacts of controlling CFCs would be substantial if the compliance time allowed was six months, but only moderate if the period were lengthened to 30 months. Other conclusions are: that conversion costs could be between $50,000 and $500,000 per line; that fillers would bear 10 or 11 percent of total loss, though they could gain offsets of 78 percent from conversions; and that marketers would absorb 46 to 49 percent of value added lost over a four-year period.

OECD's method of reaching these conclusions involved a review of the impact reports of IR&T and ADL in the U.S. and a report by Metra Consulting Group in the Netherlands. The analytical portion of the OECD report is a twenty-page synopsis of ADL and IR&T with a little extra information included from a questionnaire sent to firms in member countries. Further information regarding laws, international activities, etc. was supplied in appendices with few references concerning their origin.

Data and Its Presentation. Background data on the production of CFCs, the structure of the industry, and CFC synthesis leads to a distribution of end uses relative to total CFCs in thirteen OECD countries, and a listing of raw materials and chemicals used to produce CFCs. The ADL report and OECD's questionnaire are the principle sources of this information. The short descriptive paragraphs are followed by equally brief descriptions of how the separate segments of the aerosol industry fit together. That is, we are informed about active ingredients, container and cap manufacturing, valve production, and filling, etc. The source of these three pages again seems to be ADL's report to EPA.

Since OECD makes no attempt to estimate impacts, they also present as data for their readers the impact of alternative regulations. These impacts are more or less a summary of the IR&T report. The concluding paragraph for the section on the impact of regulating CFCs presents the IR&T study along with a Dutch study (with little mention of what the Dutch study did) as containing methodologies for the other countries to follow in their own investigations.

Summary and Conclusions. The OECD report gives a breakdown of world-wide production of CFCs. They also present a brief description of what goes into CFCs and how the separate segments of the CFC-using industry fit together. After describing several cost factors of regulating CFCs (mostly gross conversion costs and percent of lost value added absorbed by different industry segments), they provide several appendices containing additional information. Interested persons can find a summary of CFC usage by country, output, and emissions from 1931 through 1975, CFC-related activities of international organizations, legislation efforts in various countries, and a listing of possible substitutes for CFCs.

With the exception of the data on international production and some of the information in the appendices, there is very little new information in this report. Indeed, what is presented is so general as to be of little use.

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